Ergonomic and anthropometric considerations of the use of computers in schools by adolescents

ABSTRACT

Over the past decade there has been an explosion in the provision of computing facilities in schools for student use. However, there is concern that the development of these facilities has often given little regard to the ergonomics of the design for use by children, particularly adolescents. This paper reports on a study that investigated the ergonomics in the use of computer facilities by Year 8 students attending a private secondary school in Western Australia. In particular, it considered the use of computers in a number of locations in the school and the relationship between the furniture provided and the anthropometric characteristics of the students. Data collected included general physical information of the students; furniture dimensions and adjustability; and observed student behaviours. The participants all used the facilities in each of the locations so that throughout a six-month course of the study a profile of how students related to these environments emerged. Data collected supports the findings that students are less likely to engage in physically risky behaviour if they have some degree of control over their environment, particularly in being able to adjust furniture to suit their own characteristics. These early adolescent students exhibited a huge range of anthropometric characteristics leading to the need to provide adjustable furniture for use with computers. A number of recommendations are made for schools to consider as they respond to this situation.

KEY WORDS

anthropometry, ergonomics, adjustability, computers, safety

ANNA, M. JERMOLAJEW
C. PAUL NEWHOUSE

School of Education,
Edith Cowan University
Western Australia

Introduction

With the rapid advances in the development of computer technologies, and the increase in the quantity of computer facilities in Australian schools, it is important to consider the inter-linked issues of student usage, safety and anthropometry and the ergonomics of computer facilities. In 1998, the Education Department of Western Australia published 'A Framework for Implementation of Learning Technologies in WA Government Schools' (EDWA, 1998) that included levels of implementation including a target date of 2002 together with an overview of the major areas to be addressed: planning, integration and use, staff capabilities, electronic educational resources, hardware and connectivity. While the framework did determine to increase computer facilities and Internet access for all schools, ergonomics and other safety issues were not targeted as an area requiring specific consideration. This situation is not unique with a similar situation being reported by Bennett (2001) for public schools in USA. The intention in Western Australia to further increase the availability of computer facilities for students points to a significant need to ensure that computers are operated safely by this growing number of young people. A report by Wilson (1987) in Australia indicated that community based therapists were finding an increase in the number of school aged individuals presenting with, and requiring treatment for, musculoskeletal injuries and discomfort (p.249). More recently, Harris and Straker (2000) have raised concerns with the physical impact of computer use on children at school.

With this concern in mind, a study was conceived in 1998 at a private secondary school in Western Australia whichwas investing in additional computing infra-structure for student use. The establishment of a network of up to 12 computer workstations within the Library and Information Centre (LiC) for the purposes of students conducting research and word processing heralded concerns about the ergonomic design of the furniture installed with the workstations. It was felt that the layout of these computer facilities indicated adherence to what Pheasant (1996, p. 8) refers to as, the five fundamental design fallacies: if a person finds a design satisfactory then it will be satisfactory for others; it is suitable for the average person; variability amongst human beings is so diverse that no design could possibly cater for it; ergonomics is expensive and has no bearing on purchasing power though ergonomics is an excellent idea; a person designs with ergonomic factors in mind but does so intuitively. In other words little systematic concern for the ergonomics of the design was evident.

Ergonomic and Anthropometric considerations

Anecdotal evidence indicated problems with the design of the new computer environment in the LiC with problems such as when a user confined to a wheel chair attempted to access a computer and was unable to get his legs under the desk. Further, students were observed stacking chairs in order to reach the keyboard, sitting on their legs, leaning forwards or backwards, moving monitors, rearranging mouse devices, placing stacks of books under their feet to use as makeshift footrests and so on. The constant rearrangement of the furniture and computer equipment became both a time management issue and a safety concern. Several students were observed falling from stacked chairs, overbalancing, and taking an excessive amount of time to organise themselves into a physical position which enabled then to work effectively. As plans were underway to develop computer facilities in a General Purpose Laboratory for middle school students to use it was decided to investigate whether the use of adjustable furniture would overcome these problems.

Ergonomics and anthropometrics

The term ergonomics has been used extensively since computer use has become commonplace in the working and personal lives of a large proportion of the population. It particularly became prominent in the early spate of Repetitive Strain Injury cases among computer users. Stedman's Medical Dictionary (Stedman, 1995, p. 592) defines it as "A branch of ecology dealing with human factors in the design and operation of machines and the physical environment". In particular it is concerned with the design of machines, such as computers, to match the physical characteristics and constraints of the human bodies that are to use them. The science of measuring the physical character-istics of the human body and its parts is termed anthropometrics (Stedman, 1995, p. 39).

The reason to study the relationships between human beings and the artefacts and environments which they use, according to Pheasant (1996), is with "the intention of changing things for the better - either so that the performance, productivity, health or safety of the user may be improved or simply to make the user's experience a more pleasing and satisfying one" (p.2). It is Pheasant's statement that provides the basic purpose for the study conducted. That is, an assessment of the existing facilities and whether or not these can be improved in order to make the current computer facilities better aligned with the users and in doing so, increase their learning opportunities. This is a concern not only for schools but in all other environments within which people use computers (e.g. Steele & Stubbs, 2002). The consequences of not addressing these concerns can be both long-term and debilitating (Buckle & Devereux, 2002).

Grandjean (1987) states that "in order to avoid constrained postures and to guarantee easy control of machines the design of the workstation must be, among others, adapted to several elements of body size" (p.101). It becomes immediately apparent that the problem of body size variation between individuals, males and females and ethnic groups is a major factor. This is especially relevant when designing workstations for adolescents whose body size can undergo major changes over a short period of time (Harnett, 1991). This has been known for decades with, as early as the 1970s, Tanner (1973) conducting extensive research into the rate of growth in adolescents and concluded that the major growth spurt in females occurs between 10.8 and 14.0 years of age with the maximum growth occurring at 12.1 years of age, whilst males experienced a major growth spurt between 12.2 and 16.0 years of age with the maximum growth occurring at 13.9 years of age. From these figures, students in Year 8 (12 and 13 year olds) are most likely to be experiencing major physical growth changes.

Students of this age are experiencing rapid changes physically, emotionally and intellectually (Dyck, 2002). This is not a new phenonomen with Woodson (1982) explaining that these changes in body chemistry may increase restlessness, social antagonism, resistance to authority, erratic behaviour, instability and often daring behaviour. Adolescents are also experiencing significant adjustments in their first year of secondary school as in general they are entering into a larger peer group, are achieving more personal independence, and are much more at risk from peer pressure. This situation has led more recently to the growth of middle schooling initiatives in schools (Rosenfield, 2002). Research by Woodson (1982, p. 876) concluded that "the importance of conforming and of being accepted by the peer group tempts them (adolescents) to take chances that result in more serious accidents than those suffered by younger children". This risk taking has the potential to manifest itself in a number of ways and not considering personal safety when using computer facilities is an area that may provide opportunities for being seen to take risks. These factors are much more difficult to measure than bodily dimensions but need to be considered when individual safety is of prime importance, as is the case when accessing computer technology.

Kroemer and Grandjean (1997) suggest, that "most specifications for ergonomic workstations were worked out by committees in which many interested groups were represented: manufacturers, industry associations, unions, employers and ergonomists".

The resulting recommendations seem both reasonable, cost effective and in most cases suitable. However, the ergonomist who specialises in viewing the human user under practical conditions tends to view design from a different perspective. It is therefore, not surprising that field studies or practical experiences do not always confirm recommended standard dimensions. Further, most schools have limited budgets and properly ergonomically designed environments may be expensive and somewhat impractical (e.g. easily damaged by children). However, it may be that many improvements can be made in schools without exhorting to costly redesigns if principles based on anthropometric research are considered (Bennett, 2001).

Anthropometric research enables the prediction of human reach and space requirements and provides workstation designers with data enabling them to tailor workstations to suit known average figures for specific members of the population. There has been a substantial body of research over the past 30 years into the physical ergonomics associated with children and adolescents using computers (Bennett, 2001). As the numbers of computers in schools have increased and the prevalence of computers in children's home environments has also increased ergonomists and some educators have become increasingly concerned with the physical impact of use on children (Saito and Sotoyama, 2000). International research has typically shown that children exhibit poor posture when using computers (Oates, Evans & Hedge, 1998; Laeser, Maxwell & Hedge, 1998) and that this is likely to cause, among other things, back and neck pain (Murphy & Buckle, 2002). A recent survey conducted by Harris and Straker (2000) outlined the non-adjustable nature of laptop computers which may cause users to "compromise their typing posture either by increased neck flexion in order to see a lower screen; and/or by increased shoulder and elbow flexion, to reach a higher keyboard" (Harris and Straker, 2000). Due to the non-adjustable nature of the laptop computers it is highly likely that the posture problems identified by the Harris and Straker study are equally likely to occur in the fixed furniture situation researched in this study.

There have been a number of recent projects aimed at improving the ergonomic design of computer facilities in schools and to address ergonomics education in schools (e.g. Bennett, 2001). Typically these focus on furniture configuration with the use of adjustable chairs and tables and supports such as footrests and armrests, and incorporate some professional development for teachers and curriculum inclusion for students. As a result researchers have developed appropriate guidelines for schools based upon anthropometric data for children (Oates, Evans & Hedge, 1998).

According to Bridger (1995) there are three main types of anthropometrical data, structural, functional and Newtonian. Structural anthropometrical data are measurements of bodily dimensions of subjects in fixed positions. These measurements are made from one clear anatomical landmark, to a fixed point in space, for example, the height of the knuckle above the floor, the distance from the elbow to the wrist and so on.

Functional anthropometrical data are collected to describe the movement of a body part with respect to a fixed reference point. Examples of this type of data include, the maximum forward reach of a subject when sitting or standing, the area able to be swept out by the movement of the hand from a particular position These data provide information about the zones of easy and maximum reach for a person operating equipment. This 'swept' area is commonly referred to as a 'workplace envelope' and the size and shape of the 'workplace envelope' can be used to optimise workplace layout. The 'workplace envelope' size is dependent upon the bodily constraint placed on the operator and this factor must also be considered.

Newtonian data are the mechanical analysis of the loads on the human body and is primarily used to enable designers to place displays and controls in optimal positions. Newtonian data are frequently used to compare the loads on the spine caused by different lifting techniques. These data may dictate the optimal conditions for the users of the computer facilities being assessed. However, Bridger (1995) also indicates that statistical information regarding body size is not, by itself applicable to a design problem. Firstly, the designer must consider the possible consequences of anthropometrical mismatch, that is, is the feature merely an inconvenience or is it dangerous for a specific user, or actually life threatening. Newtonian data was not relevant to this study primarily because it focuses on optimal conditions for adults.

Structural and functional anthropometric data were paramount to this study as they consider the ways in which anthropometric mismatches may occur and then use the appropriate anthropometric data to combat the problem. Mismatches may only be evident when considering extremes, for example, the very tall or very short, so the researcher must make a judgement about the validity of the mismatch. Bridger (1995) does state however, that if " the design accommodates people at the extreme of the anthropometric range, less extreme people will be accommodated". (p. 8). When dealing with the changing anthropometrics of the young adolescent, this consideration, as stated by Bridger, would appear to be of considerable value when assessing and designing facilities for this user group.

Aside from anthropometric considerations, behavioural patterns of users need to be considered, as it is possible that some musculoskeletal problems may be influenced by 'reckless' behaviour and failure to observe recognized practices when engaging in seated, desk type activities. Early research by Grandjean and Burandt (1962) studying 261 males and 117 females engaged in traditional office work revealed strong links between desk height and musculoskeletal problems. A work-sampling analysis using a multimoment observation technique revealed that 15% of subjects sit forward in their chair, 52% of subjects sit in the middle of the chair, 33% of subjects sit back in the chair, 42% of subjects lean back on the backrest, 40% of subjects sit with their arms on the table, (Grandjean, 1987, p.102). These percentages indicate the percentage of worktime spent in these positions. [The two lower positions were observed simultaneously, hence causing a sum percentage above one hundred percent]. The study indicated that the desks were of a uniform height regardless of worker physical dimensions. Unfortunately the report did not

Ergonomic and Anthropometric considerations

indicate whether or not the workers observed had access to adjustable chairs. Given the date of the study it is reasonable to assume that the chairs, like the desks, were rigid in design therefore, in order to change body position workers were only able to move the chairs. This is analogous to the situation leading to the study reported in this paper.

THE STUDY

The study aimed to identify how the current metrics that were in use in a private secondary school were applied to the three main computing areas within the school, that is the Library and Information Centre (LIC), Design and Technology Laboratories (DTLs) and General Learning Centres (GLCs). The study also aimed to develop a profile of how students interacted with these environments when using computers with an emphasis on safety. The study employed an ethnographic case study methodology using both qualitative and quantitative data.

Initially an investigation was conducted in order to ascertain the current metrics, if any, already operated in the school by interviewing members of the school executive, the Head of Faculty of Information Technology and teaching staff, the Head of the faculty of Health and Physical Education and teaching staff, and the Head of Library and Information Science and associated teaching and clerical staff. Attempts to consult with the College architect provided little useful information other than to indicate that building structures conformed to existing Commonwealth government standards. No existing metrics were found to be operating within the school with regard to the design of environments for computer use. Further, the students received no formal instruction regarding the importance of posture, monitoring heights, the use of footrests, rest periods and so on when using computers.

The computer facilities

The Library and Information Centre (LIC) had a row of twelve computer workstations along one wall set on a common non-adjustable bench top. Standard school chairs, seat height 65cm were provided. The computers were set 30cm apart and the keyboards were positioned 8cm from the base of the monitors. The General Learning Centres (GLCs) and the Design and Technology Laboratories (DTLs) had single rows of twenty computers set on fixed non-adjustable bench tops around the rooms they occupied. Standard school chairs, seat height 65cm were provided. The

computers were set 30cm apart and the keyboards, with one exception, were positioned 8cm from the base of the monitors.

For the purposes of the study, a small laboratory (minilab) was established with two workstations with adjustable gas lift chairs, desk heights and anti-glare screens. This enabled comparisons to be made between the existing facilities and facilities which meet, as far as possible, international standards for ergonomics and user safety. Unfortunately it was not possible to enable students using the minilab to control the lighting as the physical structure of the minilab area was contained within the LIC and its lighting serves both areas. Users accessing the minilab were also provided with written information, in the form of annotated graphic charts and instructional charts which provided step-by-step instructions on how to adjust the furniture. The minilab equipment was initially set at the same heights as the equipment in the GLCs, the DTLs and the workstation computers in the LIC. Users had the choice of altering the settings when they accessed the minilab.

Sample, procedure and data collection

The study focused on a sample of 52 Year 8 students (28 males and 24 females) out of a year cohort of 120 students who attended the school in 1998 and who had previously attended a variety of primary schools. The sample was selected on the basis that one of the researchers taught these students on a regular basis at times when access to the full range of computer facilities within the school was available. The students in the sample group were reasonably representative of the range of socio-economic backgrounds of the students attending the school as students were randomly assigned to Year 8 classes. As they came from a range of educational and socio-economic backgrounds, commonality of experience with computer usage prior to Year 8 was difficult to determine. This prior usage may have had an influence on the issue of student safety with regard to posture, time spent using the computer without a satisfactory break, and general aptitude.

To gain parental consent a letter was sent home along with a sample of the physical data form. All participating students were provided with opportunities to become familiar with the adjustable furniture in the minilab prior to the commencement of the observation phase of the study. By enabling students to become familiar with the minilab it was envisaged that this would reduce user time spent in experimentation with the equipment and enjoying the novelty of altering the settings.

Physical characteristics data about each student were collected by a human movement specialist who individually measured each student. Measuring devices used were one set of scales, checked for

accuracy by a licensed commercial scale practitioner, six new tape measures and two calibrated measuring sticks operated by two trained adults under the supervision of the human movement specialist. Students were barefoot and dressed in sports shorts and shirts of the same design, for uniformity. The information was recorded using a Physical Data Form.

Description of anthropometric measurements

The following anthropometric measurements were made and recorded on the *Physical Data Form.*

Body weight: The student was dressed in school standard racing bathers and the weight was measured in kilograms using a set of 'Krups' bathroom scales that were checked by a commercially licensed scales technician. Each subject was weighed twice, once by the researcher and once by a qualified human movement specialist. This dual process was designed to ensure accuracy of both the process and the recorded procedure.

Standing height: The subject was stood erect with heels, buttocks, posterior aspect of the thoracic region and the head pressed against the upright portion of a stadiometer. The heels of the subject were as close together as comfort would allow and the arms hung at the sides in a natural position.

Arm length: Arm length was measured from the point of shoulder to the wrist joint using an anthropometer.

Length from waist to crown: The subject was stood erect with heels, buttocks, posterior aspect of the thoracic region and the head pressed against the upright portion of a stadiometer. The heels of the subject were as close together as comfort would allow and the arms hung at the sides in a natural position. Students were measured from the navel to the floor and the navel to the crown. Combined measurements were cross-referenced against the previously recorded height measurements. The measurement from the navel to the crown was recorded in order to obtain this measurement.

Length from waist to floor: The subject was stood erect with heels, buttocks, posterior aspect of the thoracic region and the head pressed against the upright portion of a stadiometer. The heels of the subject were as close together as comfort would allow and the arms hung at the sides in a natural position. Students were measured from the navel to the floor and the navel to the crown. Combined measurements were cross-referenced against the previously recorded height measurements. The measurement from the navel to the ground was recorded in order to obtain this measurement.

Length of hand to wrist: The subject was seated on a height adjustable chair at an adjustable table in order to obtain this measurement. The hand was placed flat on the table surface with the arm coming forward at a natural level to the table to suit the student. The measurement was taken from the wrist bone to the end of the middle finger on the right hand using an anthropometer.

Student activity observation

As the researcher taught the students involved on a regular basis, the choice of using direct observations as the prime technique for gathering the qualitative data was considered to be the most appropriate. Observation in different computer learning environments was able to take place without any interruption to normal routine and without any emphasis being placed upon their approach to the use of computer facilities. The relaxed atmosphere in which the research was conducted may have encouraged participants to behave in the manner they usually employed when using computer equipment. On average each of these students was observed twice per week for a period of no less than twenty minutes on each occasion. An *Observation Taxonomy Checklist* was developed by the researcher to assist with the compilation of data and to ensure consistency. The form was used each time participants of the study were engaged in accessing the computer facilities in the GLCs, DTL or the LIC or in the minilab. The taxonomy consisted of the following student behaviours.

■ Feet flat on floor	■ Heels raised
■ Toes raised	■ Legs crossed
■ Feet on wall	■ Footrest
■ Chair at an angle other than 90°	■ Chair stacked on another
■ Hands below keyboard	■ Hands level with keyboard
■ Hands above keyboard	■ Head tilted in a downward position
■ Head level	■ Head tilted in an upward position

ANALYSIS OF DATA

There were three discrete sets of data that were initially analysed separately and then links between these three data sets were considered. The resulting findings will be presented in the following discussion section.

Physical environment data

An analysis of the furniture used by students in the minilab and in the other locations was conducted. The results are given in Table 1. The data shows that the ergonomics of the environments at the GLCs, DTLs and LIC were similar to those observed by Grandjean and Burandt (1962) many years ago. This is an area where human requirements haven't changed while the technology has changed rapidly and often. No more comprehensive statement of recommended standard was found for comparison than that by Grandjean (1973). The students were only able to adjust the position of their chairs in order to change their body position when seated at the computers. In the minilab adjustable desks and chairs were provided. The available range of heights from floor to desk and floor to chair for the minilab are provided in Table 1. The desks could be increased or decreased in height from the floor a total of 20 centimetres by turning a wheel. The chairs were of the gas lift type and moved up or down by moving the lever on the right-hand side up or down and decreasing or increasing the weight applied to the seat.

Grandjean (1973, p. 10) states "It would certainly not be safe or wise just to extrapolate ergonomic recommendations, valuable for other places, to VDU (Visual Display Unit) workplaces". Grandjean goes on to say that "there are fundamental differences between the operations at different VDU workplaces". He does, however, make some recommendations regarding adjustability as detailed in Table 1 below.

directly as indicated earlier with descriptive statistics provided in Table 2. The other measurements can all be calculated using simple subtraction using these provided measurements.

Variations in components of a person's height are relevant to determining the correct height of a chair and the height of the monitor above the table. There was a large variation in the height from waist to crown but not a significant difference between males and

Table 1

An analysis of the characteristics of the furniture used by students to access computers.

Dimension	Locations		Recommended Standard (Grandjean, 1973)
	GLCs, DTLs and LIC	Minilab	
Furniture Type	Fixed	Adjustable	
Desk (height from floor)	65cm	50-70cm	Se p ate devices to adjust heights of desk and keyboard leve
Chair (height from floor)	43cm	40-53cm	Adjustable height and backrests
Desk (depth)	75cm	100cm	Adjustable height
Chair (depth)	38cm	53cm	No recommended standard
Distance from keyboard to desk edge	4cm	4cm-8cm	Keyboards should be movable
Distance from keyboard to monitor	8cm	4cm-12cm	Adjustable to suit user
Height of monitor above desk	8cm-24cm	8cm-24cm	Screen heights should be adjustable
Monitor angle adjustable	Yes	Yes	Yes

Students' physical characteristics data

The data provided in Table 2 were collected by measuring each participant using the standard anthropometrical measurement described earlier. These data were analysed to provide an anthropometric profile for the sample of students. Comparisons between means for males and females were conducted using t-tests and a significance level of 0.05. These measurements are relevant to the provision of furniture for use with computer workstations.

A simple descriptive statistical analysis of these data indicated the enormous potential for physical variation between students within this sample. The average age of the students was approximately thirteen years however, the youngest student was twelve years and five months and the oldest was fourteen years and one and a half months (Table 2). They ranged in height from 116 centimetres to 183 centimetres, a difference of 67cm that is a large variation (refer to Figure 1). Although, the females were on average 6cm taller than the males this difference was not statistically significant.

The key measurements for determining the ergonomics of computer user furniture are the distances from waist to crown, waist to knee, knee to foot, and length of arm and components of the arm. Some of these measurements were made

females (Table 2). However, there was also a large variation in height from waist to heel with significant difference between the mean for the males and females. The range in length from knee to foot varied up to 30% between the shortest students and the tallest students. It is of value to note that the required adjustability range, based on the range in student data, for chair height was 13cm that is the same variation possible in the minilab (Table 1). However, these chairs were designed for adult users not students in the age range being studied. So while the students required the same degree of flexibility the lowest range needed to be 5cm lower and thus some students would require footrests.

The variation in length of arms and arm components is important in determining the best position for the keyboard and monitor. The range for the sample was 49 cms (Table 2) that would indicate that students at the extremes of this range would have experienced significant discomfort. It is interesting to note that the mean arm length is 14cm greater for males than it is for females even though the average height of the female students is greater indicating that some parts of the adolescent male body are growing at different rates than these same parts for adolescent females. The variation in length of hand to wrist was also quite large with the shortest distance from hand to wrist being 9.5cm while the greatest distance was 20.5cm. The difference between the mean for males and females was significant. Similarly, length of arm and length of hand to wrist showed large variation with significant mean differences between males and females. For some measures there

Table 2

S u m my of descriptive statistics on the anthropometric data collected on the sample of students for whole sample, males and females (n=52)*.

Measure	Mean	SD	Range	Range as % of Mean
Age (months)				
Sample	156.6	4.1	149-170	13.4
Males	156.8	4.0	150-170	
Females	156.4	4.3	149-162	
Height (cm)				
Sample	161.4	13.8	135-183	29.7
Males	158.0	16.0	135-179	
Females	164.8	9.7	148-183	
Height (waist to crown) (cm)				
Sample	64.7	7.0	50.5-80	45.6
Males	63.7	6.6	50.5-80	
Females	65.9	7.5	51-78	
Height (waist to heel) (cm)				
Sample	95.5	9.0	60-110	52.4
Male	93.4	10.3	60-110	
Female	97.9	6.5	83-106	
Length of arm (cm)				
Sample	56.7	10.0	35-84	86.4
Males	63.8	10.6	39-84	
Females	49.6	22.7	35-74	
Length of hand to wrist (cm)				
Sample	15.4	2.5	9.5-20.5	71.6
Males	16.8	1.9	14-20.5	
Females	15.5	2.9	9.5-19.0	
Weight (kg)				
Sample	46.5	11.7	28-78	107.6
Males	51.7	14.1	28-78	
Females	41.2	19.0	33-70	

* 28 males and 24 females

Figure 1: Graph of the heights of sample students.

Ergonomic and anthropometric considerations
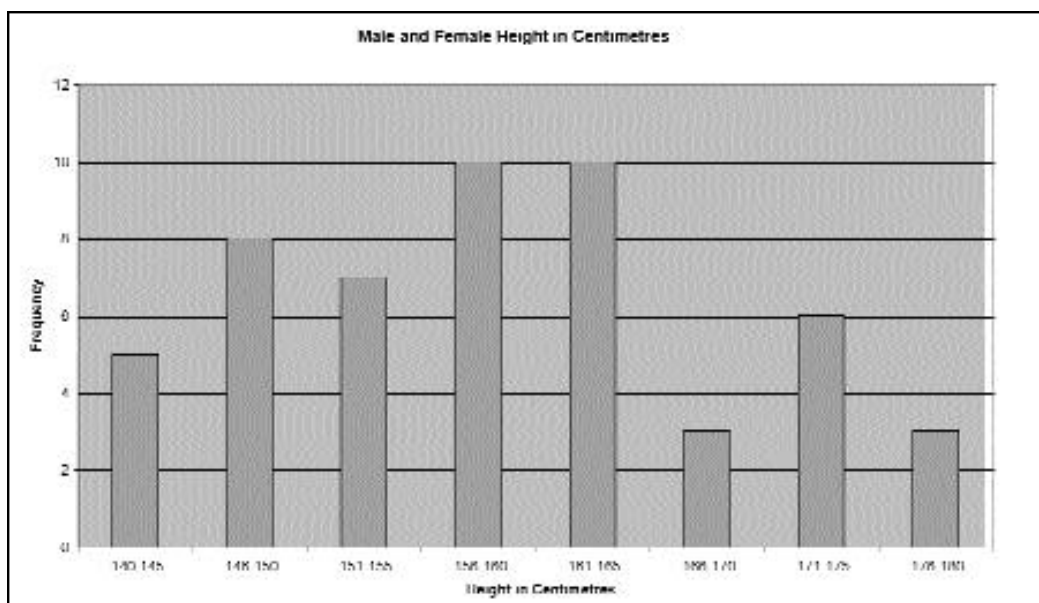
was a difference of over 50% between shortest and longest arm and hand that has implications when providing standard furniture in computing facilities for these students.

The variation in desk and chair depth required was substantial. The adjustable furniture provided a 25% greater desk depth, enabling the keyboard to be positioned up to one third further back from the desk edge. This in turn catered for a greater variety of hand and arm lengths as students were able to move the keyboard either closer to the desk edge or further away enabling a greater range of keyboard positions thereby accommodating a greater range of arm and hand lengths.

There were also large variations in weight with the average being 58.6kg that is well within the normal range for young adults. However, students varied in weight from 28kg to 78kg. This may have relevance for the types of chairs required and the effect on chairs of some student behaviours.

Data about the ethnic heritage of the students was considered to be important for inclusion because anthropometrics are based on population "norms". Therefore, it was important to discover the main ethnic heritage of the group. Not surprisingly given the geographic location of the research, 92% of the student participants were of Anglo-Saxon ethnicity. Therefore, no comparisons were made based on the ethnic background of the students.

Analysis of observation ATA

Anecdotal records of student behaviours were kept together with the use of the Observation Taxonomy Checklist. The behaviours on the checklist included both preferred and non-preferred behaviours and will be considered in three sections: non-adjustable environment; adjustable environment (Minilab); and students with disabilities.

Non-adjustable enviro n m e n

Several problems related to personal safety were immediately obvious in analysing the observation data in the non-adjustable environments (LIC, GLCs and DTLs). The standard chairs used in these environments were manufactured from moulded plastic. The legs were found to buckle under stress caused by heavier students (refer to Table 2 for weight range of students) when they were tilted or when the students leaned to one side when working collaboratively. During the study, six chairs required replacement due to buckling caused by members of this group using them incorrectly. The backs were also found to bend or in three instances snap, when heavier students leaned back or rocked on their chair.

Students were frequently observed leaning forward in their chairs in order to get closer to the monitor, thereby failing to use the back of the chair for support. This was particularly the case when the task being conducted involved word processing and graphing rather than searching. Leaning backwards at angles ranging between 5 and 40 degrees was common amongst approximately 60% of the students on each observed occasion and 3 students always sat with their feet tucked underneath them.

Students observed stacking chairs were in danger of falling off and those leaning backwards were at risk of falling backwards. During the course of the study five instances of students over balancing and falling backwards were observed. The chair stacking and leaning backwards behaviours were observed every time the LIC, GLCs and DTLs were in use and not surprisingly, tended to involve both the taller and shorter students participating in the study. Four of the shorter students were observed stacking two or more chairs on top of each other to become higher from the ground and therefore in a more direct visual line with the monitor and subsequently have their wrists higher on each occasion they used these environments. These students also placed books and or files under their feet to act as footrests. Whilst students reported no major injuries several sustained minor bruising.

Adjustable environment (Minilab)

In the minilab the settings adjusted by the students were recorded to determine whether or not students either wanted to, or needed to, adjust the settings. Students were also observed trying settings to achieve the optimum comfort. No analysis of productivity was conducted so no inferences about comfort level and productivity can be made. However, it was observed that students using the adjustable facilities developed a preference for utilising them. The demand for using the minilab facilities through choice necessitated the introduction of a roster system to ensure equity of access. The incidence of leaning backwards in chairs was eliminated in the minilab. This may have occurred because the chairs were on castors and therefore couldn't be tilted from the floor in a backwards direction or because the adjustability of the chairs enabled the user to find a comfortable position. Chairs in the minilab could not be stacked due to their design however, students were able to manipulate the chair height by up to 13cm giving greater opportunity to find a height satisfactory to their individual needs. Unlike in the other environments there were no major safety concerns observed in the minilab.

Students with permanent (one student) or temporary (three students) physical disabilities were not provided with any aids to ensure a safer or more comfortable environment. Students were unable to manoeuvre a wheelchair into a position where their legs were under the desk and needed to rest the keyboard on their laps whilst word processing or searching. These students

were also observed working side on to the monitor so they could reach the mouse. In the adjustable minilab students with disabilities were able to increase the desk height, enabling them to sit face on to the computer and use the keyboard on the desk. Access by students in wheel chairs was simplified in the minilab as the chairs were on castors and could easily be pushed out of the way without assistance.

CONCLUSIONS AND RECOMMENDATIONS

This study demonstrated the huge variation in physical characteristics of adolescent students and the resulting adjustability requirements for computer workstation furniture and the connection with poor ergonomic behaviour. These variations mean that some students require very different furniture configurations for ergonomic use of computer workstations to avoid poor behaviour. When considering the range of adjustability for the minilab furniture it was clear that some students would need footrests, otherwise there was adequate adjustability. De Alba (1993, p. 7), in his anthropometric charts, provides data that measures the physical components of the human body and indicates that 27% of body height in the age range being studied comprises the area from seat to floor. This further highlights the need for students of this age to have access to height adjustable chairs.

The study highlights the need to consider the diversity of students' physical characteristics when designing computer facilities and the necessity to provide at least some adjustable furniture. Clearly the adjustable furniture in the minilab catered for a much greater range of body sizes and shapes and is therefore, more accommodating for the often rapid physical changes that occur during adolescence. Students using the adjustable furniture, with the assistance of the charts provided, were able to place themselves in the most comfortable position for working at a computer terminal. The needs for temporarily or permanently disabled students must also be catered for during the facility design phase to ensure equity of usage and the varied needs of individuals who may be temporally disabled during the school year.

One solution for a school would be to have the fixed computer desks fixed at different heights within the same facility. Although this would not allow for a large range of size variations, it would at least provide a slightly more comfortable facility for the majority of users. The ability to shift the keyboard a greater distance would also aid student comfort and could be achieved by the addition of adjustable keyboard shelving to some or all of the existing fixed desks. This would be a relatively inexpensive solution, which would accommodate students with longer arms and hands.

Optimally however, accommodating student variations would be most easily achieved by the provision of adjustable furniture. The extent of adjustment would ideally include chairs where both the height from ground to floor and from waist to neck was adjustable, together with the ability to adjust the angle of the back of the chair to suit individual posture variations. Desk heights could be raised or lowered to enable comfortable usage regardless of individual height and keyboard distance from monitors could be altered according to length of hand and wrist.

The provision of footrests would also be of value to the shorter students, especially those whose torso may be correspondingly long in relation to their length of leg. However, such furniture must be designed to withstand the rigours of typical school environments.

Students need to be given clear information about correct posture and its importance prior to being given access to the school's computer facilities. Students need to be informed about the risks associated with incorrect posture when using computers over time. One form this information could take would be the displaying of visually explicit charts, as was provided in the minilab. The charts would need to be visually appealing to adolescents and contain messages about general safety, keyboarding and mousing, eye care, posture and the use of equipment such as foot rests and wrist rests. These charts would need to be changed frequently to ensure that students continue to notice them. With the educational trend toward cross-curricular teaching and the integration of learning technologies, all staff operating in learning areas which access the school's computer facilities need to be fully conversant with the risks associated with incorrect seating and ensure that they encourage students to minimise personal risk.

Students also require more information about their personal body requirements with regard to using computer facilities. Students are aware that their bodies are changing but not necessarily aware of how these changes may need to be considered in light of their personal well-being. The faculty members with expertise in the area of human movement could provide students with individual information about their personal needs relative to their physical structure. These staff members would also be a valuable source of information for staff regarding the importance of safe computer usage and the implications of not developing safe practices.

Students would benefit from recording their personal measurements at the beginning of the school year and then recording them again at the start of second semester and just prior to the end of the school year. Given the range of personal differences recorded at the start of this study it is likely that many of the students participating in the study would find that their personal information alters significantly over the course of the year. This information along with safety and policy information about computer usage could be included in the school diary, which is accessed by both students and parents. Teachers and teaching assistants also need to be better informed about computer safety issues in order to encourage students to take care of themselves and make optimum use of the computer facilities at their disposal.

Given the variation in student physical characteristics it is unlikely that any school dependent on current levels of funding, both government and privately provided, could cater for students to the 99th percentile. Although the financial cost of accommodating extremes is prohibitive, forward planning and a greater understanding of the variations and special needs of the adolescent body may assist in reducing the likelihood of injuries for the vast majority and permit more effective use of the technology to support learning. Concerns and knowledge about the ergonomics of using computers are not new but with the increased use of the technology by

Ergonomic and anthropometric considerations

children at home and school these concerns are becoming more compelling and should lead schools to re-evaluate the design of environments within which the technology is used.

REFERENCE

Bennett, C.L. (2001). Classroom and computers: an elementary school case study. In A.C.

Bittner, P.C. Champney, and S.J. Morrissey (Eds) *Advances in Occupational Ergonomics and Safety* Vol. 4, 354-360, The Netherlands: IOS Press.

Bridger, R.S. (1995). *Introduction to ergonomics.* New York: McGraw-Hill.

Buckle, P. and Devereux, J. (2002). The nature of work-related neck and upper limb musculoskeletal disorders. *Applied Ergonomics,* 33, 207-217.

De Alba, R. (1993). *Measure of man and woman: human factors in design (2nd ed.).* Edited by Alvin R. Tilley. New York: Henry Dreyfuss.

Dyck, B.A. (2002). Hovering: teaching the adolescent brain how to think. *Middle Ground,* April, 18-22.

EDWA (1998). *A Framework for Implementation of Learning Technologies in WA Government Schools.* [on-line]. Available: www.eddept.wa.edu.au/

Grandjean, E. (1987). *Ergonomics in computerized offices.* London: Taylor & Francis.

Grandjean, E. (1973). *Ergonomics of the home.* London: Taylor & Francis.

Grandjean, E & Burandt, H.W. (1962). *Sitting Habits of office employees.* Ergonomics, 13, 195- 202.

Harnett, A. (1991). Preparation of middle school teachers. *ERIC Digest 90-1.* ED335356.

Harris, C.and Straker, L. (2000). *Survey of physical ergonomics issues associated with school childrens' use of laptop computers.* [on-line]. Available: http://physiotherapy.curtin.edu.au/home/staff/straker/publications/2000laptopfolder/2000IJIElaptop.html

Kroemer, K.H.E.and Grandjean, E. (1997). *Fitting the task to the human: a textbook of occupational ergonomics.* (5th ed.) London: Taylor & Francis.

Laesar, K.L., Maxwell, L.E. and Hedge, A. (1998). The effects of computer workstation design on student posture. *Journal of Research on Computing in Education,* 31(2), 173-188.

Murphy, S. and Buckle, P. (2002). Association between back pain and posture on schoolchildren. *Contemporary Ergonomics,* 106-111. London: Taylor and Francis.

Oates, S., Evans, G. and Hedge, A. (1998). A preliminary ergonomic and postural assessment of computer work settings in American elementary schools. *Computers in the Schools,* 14 (3/4), 55-63.

Pheasant, S.T. (1996). Bodyspace: anthropometry, ergonomics, and the design of work. London: Taylor & Francis.

Rosenfield, J. (2002). Surfing the brainwaves. *Middle Ground,* April, 10-16.

Saito S., & Sotoyama, M. (2000). Research activities on the ergonomics of computers in schools in Japan. In *Proceedings of the International Ergonomics Association and Human Factors and Ergonomics Society* (IEA/HFES 2000), Human Factors and Ergonomics Society, Santa Monica, CA.

Stedman, T.L. (1995). *Illustrated Stedman's Medical Dictionary. 26th ed.* Baltimore, MA: Williams & Wilkins.

Steele, D. and Stubbs, D. (2002). Measuring work posture of midwives in the healthcare setting. *Contemporary Ergonomics,* 39-44. London: Taylor and Francis.

Tanner, J.M. (1973). *Sequence, tempo, and individual variation in growth and development of boys and girls aged twelve to sixteen. In Twelve to sixteen: early adolescence.* Edited by J. Kagan and R. Coles. New York: Norton, pp.1-24.

Wilson, J.R. (1987). *New methods in applied ergonomics: the proceedings of the Second International Occupational Ergonomics Symposium.* Zadar, Yugoslavia, 14-16 April 1987. Edited by John R. Wilson, E. Nigel Corlett and Ilija Manenica. London: Taylor & Francis.

Woodson,W.E. (1982). *Human factors design handbook: information and guidelines for the design of systems, facilities, equipment, and products for human use.* New York: McGraw-Hill.