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Survey of physical ergonomics issues associated with school childrens' use of laptop computers.

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ABSTRACT
The survey investigated the use of laptop computers by children aged 10 to 17 years at schools in Western Australia. Data collected included general participant information (eg. age, height); locations and postures adopted for laptop use; time on task and consequences of both using and carrying laptops. 251 participants used the internet to complete the survey and 63 completed written surveys. Twenty participants were interviewed and observed using their laptops in various locations. The mean times for minimum and maximum periods of laptop use at one sitting ranged from 11.5 - 101.9 minutes. Mean daily use (3.2 hours) and weekly use (16.9 hours) was also shown to be high. Postures used by laptop users varied according to location, eg. home, school and boarding house. Reported consequences of laptop use included technical faults, service and location limitations, hardware and software limitations, user limitations and physical consequences to the user. 60% of students reported discomfort with laptop use and 61% of participants reported discomfort with carrying their laptop. Associations between school attended or year level with time on task and discomfort reports were evident.

RELEVANCE TO INDUSTRY
The use of laptop computers is increasing, both in educational settings and other industries. There is however minimal research on the physical consequences of laptop use by adults or children, and therefore recommendations for using laptop computers are tentative.

KEY WORDS
ergonomics, laptop computers, children, posture, discomfort

INTRODUCTION

The use of information technology in all areas of life is rapidly increasing, and this is particularly evident within the school system. Australia is pioneering the use of laptop computers within the school environment, particularly within the private education system. Additionally, laptop computers are one of the fastest growing trends in the world of business today (Steelcase 1997) and currently the single largest growth area within the personal computer market (Harbison et al. 1995).

Educational literature on the use of laptop computers by school children has been favourable with many benefits being promoted. The attraction to use this type of computer is due to their size and thus portability. A portable computer allows for a greater flexibility of learning environments, greater access to information throughout the learning process, is reported to be fun and provides the opportunity for students to be independent cooperative learners (Shears 1995 and McDonald 1995).

At present however community based therapists are reporting an increase in the number of students requiring treatment for musculoskeletal injuries and discomfort (Wilson 1997). This increase in the number of students as patients has been suggested to be related to students' increased use of computers.

When reviewing the literature there is minimal research reported on the use of laptop computers and the physical implications of their use, both within school and general environments. At the time of this research only four published studies were found that discussed the physical implications of using laptop computers (Diederich and Stewart 1997, Harbison and Forrester 1995, Price and Dowell 1998, Straker, Jones and Miller 1997). The physical implications for the use of desktop computers are well documented. These implications may be able to be generalised to the use of laptop computers, for example in regards to static postures utilised, screen viewing distances and angles, screen height, upper limb and neck postures. However as laptop computers are designed differently the implications of their use will also be different from desktop computer use.

It is generally thought that to minimise discomfort during computer use workers should change postures frequently. Such postural changes are best supported by adjustability within the work station (Jacobs and Bettencourt 1995). Adjustable work stations also allow for the anthropometric variability between individuals using work stations (Straker et al. 1997a). An adjustable computer work station can therefore contribute to a range of suitable working postures for the user. Therefore a work station that is not adjustable (without adjustable screen height and distance) is not recommended for prolonged use (Diederich and Stewart 1997).

The work station for a desktop computer user should be adjustable by having at least an independent keyboard and screen and well designed furniture. Research suggests that computer work stations that promote awkward or constrained body postures predispose the user towards musculoskeletal injury, and that persistent musculoskeletal problems relate to poor work station design and adjustability (Harbison and Forrester 1995).

As laptop computers generally have their screens fixed to the keyboard, there is not the adjustability in the work station that is expected and recommended in a desktop computer work station. The laptop user can adjust their viewing angle, however independent adjustment of the screen and keyboard distance and height cannot be made if external equipment is not utilised. The height and distance of the screen impacts on the users' head and neck posture and the height and distance of the keyboard probably affects neck, shoulder, arm and trunk posture. This can therefore lead to the laptop user assuming an awkward posture to operate the laptop computer.

Straker et al. (1997a) suggest that a laptop user would assume a posture for use that would 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. This is further supported by Harbison et al. (1995), who found that laptop users required an

increased forward head inclination to adequately operate the computer due to its lack of adjustability.

The forward head inclination posture adopted by all laptop user subjects in Harbison and Forrester's (1995) study, was more than 30 degrees greater than the recommended neck posture as outlined in Australian Standard 3590.2 (1990). The mean head inclination angle ranged from 44.0 to 49.6 degrees depending on the location of use. In contrast to this ergonomists have stated that the head and neck should not be bent forward by more than 15 degrees otherwise fatigue will be experienced (Grandjean 1987), although this is debated (Straker, in press b).

It is therefore proposed that the laptop user is likely to assume an awkward, constrained posture when typing due to the design of the laptop. From our knowledge of awkward postures with desktop use we can predict that laptop users could therefore experience musculoskeletal discomfort and problems with laptop use (Price and Dowell 1998). Laptop user problems could occur from awkward postures but also, like desktop user problems, could occur from the length of time these postures are maintained.

Kroemer (1989, p.279) recommends that to avoid cumulative trauma disorders a person should not maintain a body posture for "long periods of time". This is well recognised in the literature in order to prevent static loading of muscles and therefore muscle fatigue, impaired circulation and a pain-spasm cycle (Carter and Banister 1994). However the phrase "for long periods" is not quantified. Research alternatively discusses this issue by suggesting that a computer user should take frequent breaks, vary their seated posture throughout the work day and/or be able to rotate their work stations to adopt different work postures at different work stations (Carter and Banister 1994). The length of time recommended to use the computer for in one sitting or posture type is not quantified.

Straker et al.'s (1997a) study on postures assumed for laptop and desktop computers demonstrated that after twenty minutes all participants reported some areas of discomfort eg. pain, headaches and muscle fatigue, mainly in the neck and upper back.

The detrimental effects on performance and the users' health by a small change in posture have been documented by Straker et al. (1997b), in their study on shoulder postures with typing tasks. Their study demonstrated that after 20 minutes of typing participants with zero degrees shoulder flexion performed better on the task and had less discomfort and fatigue than those subjects using 30 degrees of shoulder flexion for typing.

Based on these studies, postures assumed for periods of time greater than just 20 minutes could lead to musculoskeletal problems for the user.

Therefore the type of postures utilised for laptop computer use, and the length of time these postures are maintained, could lead to adverse effects on the user's health, satisfaction and performance.

As minimal information was available on these issues generally, and especially with regard to school children, the aim of this study was to investigate the use of laptop computers by school children. In particular, the study investigated the postures adopted for laptop use, the length of time laptops were used, and reports of problems with laptop use.

METHOD

Design

A two phase descriptive study was used to collect qualitative and quantitative data. Phase one of the study involved surveying 314 school children to gain a broad perspective on how school children were using their laptop. Phase two of the study involved directly observing 20 students (from years 8 and 9 at School B) using their laptop computers to gain more detailed information on particular postures and environments utilised for laptop computers. Phase two was also used to check the accuracy of responses to the phase one internet survey.

Participants

Three hundred and fourteen students aged from 10 to 17 years, in school years 5 to 12 from three private schools within Perth, Western Australia participated in the study. Eighty percent of students completed a World Wide Web questionnaire via the internet, whilst the remaining 20% used printed questionnaires (due to a temporary loss of internet connection at one school).

A year 8 sample across all three schools was taken to enable the study to compare laptop use across different schools. The sample of students from years 5 to 12 at one particular school was taken to enable the study to compare laptop use across different year levels.

Variables

Height data were collected to enable the study to gain anthropometric data on the sample and compare height data to reports of discomfort with laptop use.

Students' school and year attended were collected to identify if these variables related to time on task or discomfort experienced by the students.

Discomfort with using and carrying laptops was collected to enable the study to identify which activities resulted in discomfort.

The questionnaire is viewable at http://www.curtin.edu.au/curtin/dept/physio/pt/staff/straker/publications/2000Laptopfolder/1998survey.html.

Ethical considerations

Participation in the study was via voluntary informed consent, and procedures were passed by the Curtin University of Technology Human Research Ethics Committee.

RESULTS

General information

Thirteen percent of students surveyed were male and 87% female. Ages ranged from 10 years 1 month to 18 years and 7 months; with the mean age of 13 years and 2 months. Mean height of students was 1566mm, with the range from 1039mm to 1834mm.

Participants were drawn from years 5 to 12 from one school (A) with a larger sample for year 8 coming from all schools (A, B and C), as shown in Table 1.

Table 1. Participant's School and Year Level

Year Level	School			Total
	A	B	C	
5	1			1
6	17			17
7	28			28
8	97	16	63	176
9	26	16		42
10	12			12
11	24			24
12	14			14
Total	219	32	63	314

Participants at School C used Newton Emates exclusively, whilst students from Schools A and B mainly used Apple Macintosh and Toshiba laptops, as shown in Table 2.

Table 2. Types of Laptop Computers Utilised

Laptop Type	Students Using n (%)
Newton Emate	63 (21%)
Apple Macintosh	156 (52%)
Toshiba	73 (24%)
Other	8 (3%)
Total	300 (100%)

Table 3, describes the number of participants using other equipment with laptop computers, and the locations the equipment was used in.

Table 3. Equipment Utilised with Laptop Computers

Equipment Type	Locations			
	School	Home	Boarding House	Other
External Desktop Monitor	59	34	3	10
External Keyboard	49	37	4	10
Adjustable Desk	85	56	4	11
Standard Fixed Desk	174	187	22	20
Footstool	26	38	1	15
Adjustable Chair	101	153	8	18
Standard Fixed Chair	207	142	18	21
External Mouse	48	56	9	12

Laptop use

The mean minimum time for students using laptops for any one sitting was 11.5 minutes. The mean maximum time was 101.9 minutes (ranging up to 10 hours). The mean daily use each school day was 3.2 hours (ranging up to a maximum of 15 hours), with a mean weekly use time of 16.9 hours (ranging up to 80 hours).

Laptops were reported to be used in a wide variety of locations, as shown in Table 4.

Table 4. Locations for Laptop Use

Location	Number of Participants
School	308
Home	296
Boarding House	34
Transport (in car, bus, plane)	31
Others homes	17
Excursions, “anywhere”	9
Holidays	7
Other school areas (gym, library)	7
Work (self or parents)	4

The posture used by most participants was desk sitting (84%) followed by lying prone and floor sitting (See Figure 1). However desk sitting only accounted for 34% of the mean weakly use, with laptops being used in non desk sitting postures for 66% of the time (See Figure 2).

Figure 1: Percentage of Participants Using Different Postures for Laptop Use

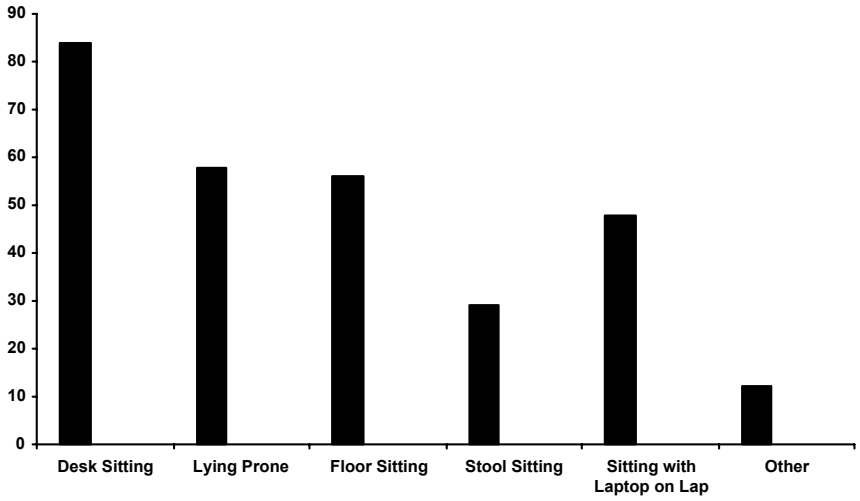

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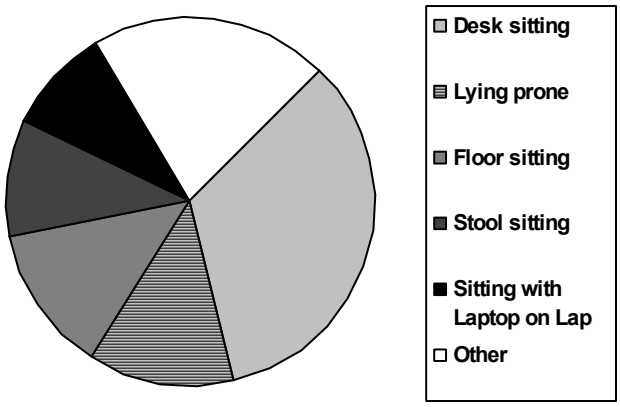
Figure 2. Postures for Laptop Use by Proportion of Mean Weekly Use



Other postures used for laptop use included; sitting on bed, sitting cross legged, standing, sitting and leaning against a wall with laptop on flexed knees, kneeling, lying supine, side lying, side sitting, slouching whilst seated, resting laptop on hand / arm and sitting on floor with laptop on a desk or chair.

Of the postures adopted for laptop use at school the most commonly used postures included; sitting at a desk or floor. At home the most commonly used postures included; sitting at a desk, floor, beanbag step or stool; lying on bed or floor or sitting with laptop on lap. In the boarding house the most used postures included; lying on bed or floor and sitting on the floor or at a desk.

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The time a participant used a laptop for was related to their year level and school attended. Table 5 demonstrates the analysis.

Table 5. Chi Square Analysis for the Association of School and Year with Laptop Use Duration

Laptop Use Duration	Year Level		School Attended	
	χ^2	*p*	χ^2	*p*
Daily	$\chi^2_{28}=67.63$	.0001	$\chi^2_{8}=31.25$	.0001
Weekly	$\chi^2_{28}=61.80$	.0002	$\chi^2_{8}=22.61$	.0039
Minimum time	$\chi^2_{35}=58.78$	.0072	$\chi^2_{10}=24.37$	.0067
Maximum time	$\chi^2_{28}=46.46$	.0156	$\chi^2_{8}=19.38$	.0129

Consequences of use

A summary of the general problems reported by participants is detailed in Table 6.

Table 6. General Problems Experienced With Laptop Use

Problems	Participants Reporting Problems
*TECHNICAL FAULTS, eg. - keyboard sticks / break - screen breaks / freezes / dims - resets itself - printer doesn't work - lose files - doesn't always start - viruses - breaks - mouse / touch pad doesn't work - network faults	33%
*HARDWARE & SOFTWARE LIMITATIONS, eg. - not colour - loose mouse on screen - programs don't run / difficult accessing programs - small screens / difficult to see - too slow to perform functions - limited power supply, requiring recharging frequently - small keyboard / difficult to type - not enough memory	41%
SERVICE / LOCATION LIMITATIONS, eg. - no printers at home / not enough printers, need to queue - not enough power points - difficult to store in bags / lockers, not enough room	4%
*USER LIMITATIONS - slow typing	3%

User Discomfort
A high proportion of students reported discomfort with using and carrying their laptop computers, 60% and 61%, respectively.

Figure 3 demonstrates frequency of discomfort locations participants reported when using and carrying their laptops.

Figure 3 Body Map Showing Discomfort Frequencies when Using and Carrying their Laptop Computer

There was no statistical association between height of participants and discomfort (χ^2_5=4.4, p=.567).

The study demonstrated an association between the type of computer used and discomfort with carrying (χ^2_3=65.0, p=.0001). Students using Apple Macintosh Newton Emate computers were found to have markedly less than expected levels of discomfort with carrying this type of computer. Students using general Apple Macintosh and Toshiba laptop computers, which are bulkier and heavier than the Emate computers, demonstrated a higher than expected level of discomfort when carrying their laptop. Newton Emate computers weigh 1.8 kgs and easily fit into an average sized school bag or are comfortably carried by a gross palmar grasp. Apple Macintosh and Toshiba laptop computers weighed approximately 4 kgs, and are usually carried in their own bag with a shoulder strap. Figure 4 illustrates these types of laptop computers.

Figure 4: Photograph of the Three Types of Laptop Computers Utilised (a Toshiba, b Apple Macintosh Powerbook, c Apple Newton Emate).

The study also showed an association between the school the participants attended and discomfort with carrying (χ^2_2=63.58, p=.0001). Students from school C, who all used Newton Emate laptops, demonstrated less than expected levels of discomfort. Students from schools A and B using general Apple Macintosh and Toshiba laptop computers experienced a greater than expected level of discomfort. Some of the participants from schools A and B have also been using laptop computers for longer (more than one year) than participants in school C (less than 3 months). Therefore the length of time they have been using and carrying their computer may have contributed to the development of discomfort experienced.

The survey demonstrated that students in some years experienced more discomfort with using their laptop than other years (χ^2_7=15.75, p=.0275). For example students in years 9, 10 and 12 experienced as much or more discomfort than expected. This could be due to these students using their laptops for several years as some started using their computers in year 5 or 8, depending on the school they attended. This could also be attributed to the average maximum time spent in one sitting for these students was 132 minutes, which is greater than the overall average of 102 minutes. Mean daily and weekly use was less for year 9, 10 and 12 students suggesting maximum time on task is more important than overall time spent using a laptop.

Interestingly year 8 students demonstrated a less than expected level of discomfort. As mentioned, this could be attributed to the fact that at least 20% of the sample were year 8s from school C who had only been using their laptop computers for approximately 2 months prior to the survey. School B also had a small percentage of year 8s who had transferred to the school recently and had also only been using laptop computers for a couple of months.

The survey demonstrated that students in some schools experienced more discomfort with using their laptop than students at other schools (χ^2_2=5.81, p=.0548). Although the association is weak, students from schools A and B experienced greater than expected levels of discomfort. Given the length of time these students had been using their computers (up to seven years) and the type of computer they were using, this is not a

surprising result. School C which demonstrated less than expected levels of discomfort is consistent with this as these students have only used their computers for a couple of months prior to data collection and used the lighter laptop.

With regard to time on task and discomfort, the survey indicated an association between maximum time on task and discomfort only (χ^2_4=16.51, p=.0024). Statistically there was no association between daily (χ^2_4=2.56, p=.6346), weekly (χ^2_4=7.38, p=.1172) and minimum (χ^2_5=5.15, p=.3973) time on task and discomfort.
Two thirds of students reported that they would change position or move when experiencing discomfort. Other coping mechanisms included: continue on with the task (26%); don't think about it (18%), stop and do something else (16%), see someone for treatment (3%), stretch or exercise (29%) and swap hands / shoulders (1.5%).

DISCUSSION

Study Design

The results of the survey were dependent on children completing questionnaires either on the internet or paper. As with all questionnaires the validity of the information relies on participants understanding the question and answering honestly and accurately. Phase two of the study enabled cross validation of responses by a sub sample, which together with internal consistency checks in the questionnaire, suggests the data were mainly accurate.
Phase two also enabled a check on the adequacy of the posture descriptions used in the questionnaire. Whilst some novel postures were found, the postures represented in the questionnaire did accurately reflect the more common postures adopted during laptop use.
The World Wide Web form was an efficient medium to use to reach a large sample as responses were automatically coded for transfer to statistics software for analysis. The process was dependent on all participants having access to the internet, either from school or home.

As with all surveys the internet survey required consideration into the format the survey took. An advantage of the internet was that computer technology could assist with graphics and layout. The survey was designed to be as simple as possible and a majority of responses required only selecting options using a mouse.

Whilst the sample was biased towards females, because of the schools used, we do not believe this substantially influenced the results.
As no prior survey of school childrens' use of laptop computers was found, the survey gained valuable information for ergonomists, computer specialists and educationalists. Information on consequences of use spanned issues such as technical faults, hardware and software limitations, service and location limitations, user limitations as well as physical consequences for the user.

Postures and time on task for laptop use

Laptop computers allow the user great variety and flexibility in work posture and work locations, due to their size and portability. As demonstrated in the survey, school students would often use postures such as sitting on the floor, lying prone, sitting in a beanbag in a variety of locations, eg. home, cars, school, friends' houses.

However 60% of participants reported discomfort from using their laptop computer. This may be attributed to the design of the laptop computer resulting in awkward postures for use, and also due to the length of time the participants used their laptop computers for in terms of total time used and time in one sitting. The study demonstrated that with increased time on task in one sitting more discomfort resulted. Participants also demonstrated high daily and weekly laptop computer use.

This relationship is further supported by Hochnanadel (1995) who surveyed 3300 employees using computer work stations in a large industrial complex and demonstrated significant relationships between the percentage of symptomatic respondents and both the hours and years of computers use. The percentage of symptomatic respondents increased in each group as the average hours and years of computer use increased. As the average daily hours

increased, the percentage of symptomatic respondents increased at a greater rate than that for years of computer use.

Additionally, user discomfort may result from the variety of non traditional work postures often utilised due to the portability of the laptop computer. Students are using the laptops in a great variety of work postures and locations. Therefore the user may be assuming work postures for computer use that are putting the body into unnatural postures. For example lying prone to operate a laptop computer could result in increased neck extension and a compromised upper limb that not only needs to operate a computer, but bear the upper trunk weight to sustain the position. The actual position adopted as well as time spent in the posture could be unfavourable.

Body Map discomfort locations
Body Map discomfort locations such as neck, shoulder, arm, hand and legs are often reported not only for computer users but also other office machinery users (Carter and Bannister 1994, Harbison and Forrester 1995, Hochnanadel 1995, Hunting et al. 1981). These locations were also reported by participants for laptop use.

Additionally head and eyes were also indicated as a source of discomfort for participants. This may be attributable to the smaller size of laptop screens and perhaps the clarity of the screen display, resulting in eye strain and headaches. Neck and upper limb discomfort and muscle tension could also have resulted in associated headaches.

Respondents reported more shoulder and back discomfort than head, neck and arm locations with laptop carrying, which is consistent with predicted biomechanical loads.

Computer type and discomfort
Schools A and B primarily use general Apple Macintosh and Toshiba laptop computers, whereas School C utilised Newton Emate laptop computers. The general laptop computers have large hard drives and therefore the ability to perform many functions from a range of software. Emate computers are smaller in size and ability and primarily have a word processing function.

The study demonstrated that students from school C demonstrated a less than expected level of discomfort with both carrying and using their computers. This is probably due to the type of computer used, but may be due to these students having only been using their laptops for approximately 2 months at the time of data collection.

Carrying laptop computers
The survey indicated that 61% of students reported discomfort with carrying their laptop. This is further supported by McDonald (1995) who stated results from her survey indicated that 60% of students reported that the laptop computers were too heavy to carry home. Computer type and discomfort were associated and it appears the trade off of having a smaller, light weight computer such as the Newton Emate, that may only perform specific functions for school use, is physically better for students than a larger laptop that has a variety of functions and facilities.

CONCLUSION
This study has gained valuable information on the use of laptop computers by school children, that can be generalised to other computer dominated environments. Findings are preliminary in some areas and thus it is imperative that further research into the use of laptop computers be performed.

Laptop computers are valuable tools within the school environment, and many of the consequences of their use do have solutions. However this research suggests that school children are exposing themselves to prolonged poor postures with laptop use that is leading to discomfort. This is of particular concern as it occurs during critical periods of their skeletal growth. Students are also reporting discomfort with transporting laptops and problems with maintenance and servicing these computers that should also be addressed.

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These findings therefore suggest that schools and other organisations undergo careful consideration when deciding to use this type of technology, and then how they teach users to operate laptop computers.

Whilst this study has identified the potential physical implications of laptop use by school children, it has not investigated solutions. However based on prior research the following tentative guidelines may be useful in trying to prevent discomfort associated with laptop use by school children (Straker in press a).

1. Use a variety of mid joint range, supported postures
2. Take frequent posture breaks allowing joints to stretch and move
3. Use the laptop with an external monitor to allow independent adjustment of keyboard and screen
4. Minimise use in environs which give annoying reflections and glare
5. Use a laptop with best quality screen
6. Use the least heavy laptop
7. Use a comfortable back pack with two shoulder straps or a wheeled case to carry the laptop

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