CAKE

(Computers and Kids' Ergonomics):

The Musculoskeletal Impact of Computer and Electronic Game Use on Children and Adolescents

by

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Manny Halpern

Dedication

To my mother, Faith Gillespie, who didn’t live to see it but always saw it coming.

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Finally, a promise to my family: Some things will change. Some won't.

Abstract

Computer and electronic game use were proposed as contributors to neck or upper extremity (NUE) symptoms of pain or discomfort occurring in adolescents. A cross-sectional survey distributed in general education classrooms in a northeastern US city produced 476 analyzable surveys, representing 75% of solicited subjects and 10% of the entire school population age 12-18. Subjects reported frequency, average daily duration and typical longest period of computers at school, computers at home, TV-based games, and hand-held games, as well as symptoms occurring in the past month and symptoms frequency and intensity ratings.

In unconditional logistic regression analyses adjusted for gender, age and race, frequent home computer users (daily or almost daily) were at increased odds of reporting NUE symptoms compared to less frequent users (OR=1.7, p=0.008). Those who used the computer at home for longer without a break also had higher odds of NUE symptoms, but those reporting higher average daily use time did not. School computer use and electronic game use were not associated with increased NUE symptoms.

The effect of daily home computer use on NUE symptoms was seen primarily in high school students. However, age itself did not predict NUE symptoms.

Age, race and gender did not affect the relationship between computer use and symptoms. However, girls were more likely to report NUE symptoms than boys (OR=1.9, p=0.005). Being overweight and wearing glasses or contact lenses were also associated with symptoms. As computer use patterns and weight are modifiable

characteristics, they suggest targets for reducing the negative effect of computer use in this population. Additional research and interventions involving the roles of physical activity, equipment design, psychosocial demands and physical development are recommended.

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Chapter 1   Background

1.1. Introduction

Children and adolescents are increasingly engaged in activities that simulate work demands known to cause repetitive strain injuries in working adults. From the earliest years, children use computers at home and school. Nursery schools and commercial play spaces advertise computer classes, computer games are produced for every age and interest, and reference materials are sold on CD-ROM. But desktop computers are not the only way kids interact with computer technology. Notebook computers are issued to middle-school students. TV-based video games are found in 70% of households with children (Roberts, et al., 1999). Handheld games are used everywhere, including the playground and school. Given the widespread and increasing use of computers and electronic devices, it makes sense to ask if children use this technology in physically risky ways, and if they experience pains or clinical problems related to that use.

Computer use at work has been implicated in the development of musculoskeletal disorders. In adults, using a computer keyboard at work is thought to be associated with musculoskeletal symptoms and clinical disorders in the upper extremities, neck and upper back (Bernard, 1997, National Research Council and Institute of Medicine, 2001). Posture, duration, frequency and force are the exposure parameters of concern. Children using computers and electronic games may well adopt the kinds of sustained and awkward postures that are associated with musculoskeletal disorders in working adults.

The physical demands of extensive use could lead to a wide range of adverse effects on developing children, including visual, neurological and physical changes. (Cognitive and behavioral effects are also possible; these are reviewed extensively elsewhere (Behrman, 2000, Cordes and Miller, 2001, Emes, 1997, Wartella, et al., 2000).) Some researchers have suggested that computers and games encourage more awkward postures or intense concentration in children than do TV watching or schoolwork, indicating that children's risk of musculoskeletal disorders may be greater than in other sedentary activity (Gunzburg, et al., 1999, Szpalski, et al., 2002).

This chapter reviews the ergonomics, epidemiology and clinical literature that address some of the questions related to the physical impact of computer use by children. It is a revised version of an article published in the course of preparing for this dissertation work (Gillespie, 2002). The chapter does not delve into the extensive literature on the cognitive impact of computer use and only in passing will describe the related literature of classroom ergonomics. Although the question of why computers and similar devices are used so extensively and intensively is clearly germane to the issues of impact, health effects and prevention, it is beyond the scope of this discussion.

1.2. A review of current literature

Four distinct research streams provide insight into the impact of computer and electronic game use on children. Computer use literature describes the frequency and duration of computer use as well as electronic games use, television watching and other related activity. Workstation research attempts to analyze the goodness of fit between children and computer workstations, typically in the classroom. Musculoskeletal symptoms research provides rates of musculoskeletal disorders in children, defined in many ways and covering children of diverse ages, nationalities and health statuses. Health effects research investigates the link between physical effects and computer use parameters of frequency, duration, posture and ecology. Effects of interest typically include musculoskeletal pain, visual problems and physiological changes. These research streams set the stage for any epidemiological study of musculoskeletal problems associated with children's computer and electronic game use.

Finally, preventive measures research intervenes, typically in the classroom, to change how computers are set up and used, and measures the impact of the intervention on changes in health outcomes or presumed intermediary variables such as behavior. Ideally, intervention research is based on knowledge derived from all the preceding research streams.

1.2.1. Patterns of computer use

Many children already use computers intensively, at school and play. Home use of games and CD-ROMs can occupy even very young children for hours, as do television-based video games and hand-held toys. Parents, receiving the message that children who don't use computers will miss out on academic and work success, encourage computer games and learning activities.

Media use has changed dramatically in the past 15 years. The Longitudinal Study of American Youth found that only one in fifty kids in 1990 used a computer outside of class for ten or more hours during a school year (Rocheleau, 1995). Just ten years ago, research on children's computer use characterized significant classroom computer use as more than ten times per subject in the school year (Pelgrum, 1996). Now researchers are asking about daily use, about minutes or hours per day, and about several different types of media interfaces (Roberts, et al., 1999, Stanger and Gridina, 1999, Woodard and Gridina, 2000, Wright, et al., 2001).

Several major surveys have catalogued computer use in the home and at school. As of 2003, 97% of children in grades 9 through 12 and 91% of 6-8 graders used computers (National Center for Education Statistics, 2005). Access to the Internet was reported by 80% of the older students and 70% of the younger. In 2000, 89.6% of children aged 6 to17 had access to a computer, 65% at home and 80% at school (Newberger, 2001). Just three years earlier, 74% of children had some access to a computer, 50% at home and 70.8% at school (Newberger, 1999). In 2000, the NPR/Kaiser Family Foundation survey found that 78% of telephone survey respondents had a computer at home (Rosenbaum, et al., 2000). Clearly, computer use by children has increased and virtually all school-aged American children now have some access.

The Media in the Home annual telephone survey characterized duration of home use as well as access (Woodard and Gridina, 2000). According the results for 2000, seventy percent of families with children between 2 and 17 had computers and 68% had video games. Based on parent reports, the average child used a computer for 34 minutes a day, the Internet for 14 minutes and a video game for 33 minutes. Screen media use for all children, including television, videotapes, Internet, computer and games, exceeded four and a half hours. At 281 minutes per day, this was up 21 minutes from the previous year. Predictably, media use increased with age, although video game use did not increase between the 6-11 and 12-17 age groups. VCR use decreased with age. Parents reported that adolescents spent 164 minutes daily on computers, Internet and video games and another 195 minutes watching television and videotapes, for a total of six hours of screen exposure. In one Australian study of laptop use, average daily use in the past month was 3.2 hours; the highest total daily use reported was 15 hours, with a mean longest single period of use of 102 minutes (Harris and Straker, 2000).

The Kaiser Family Foundation reports from classroom survey results that in 2000, children spent an average of five hours and 29 minutes on all media combined (including music and reading) (Roberts, et al., 1999). Nine percent of all children used a computer for more than an hour a day, and 8% played video games for more than an hour. In a related telephone survey, 57% of these children used the computer almost daily. (One caveat about generalizing this result is that the next level of use offered to respondents was "about once a week," which clearly could inflate the apparent use. This group was also notably higher in access and use than others surveyed.) In general, researchers caution against summing up media use because of extensive multitasking (Papper, et al., 2004, Roberts, et al., 1999, Stanger and Gridina, 1999, Tice, 2003, Woodard and Gridina, 2000).

Averaging over all children reduces the apparent load of computer use, of course. Among computer users aged 8-18, average daily use was 101 minutes. The 1999 Media in the Home survey provided evidence that heavy media users are heavier across the board, with computers and electronic games being added to television watching rather than replacing it (Stanger and Gridina, 1999).

A national survey of children's electronic media use in 1997 analyzed 24-hour time use diaries from 2902 children aged 0 to 12 (Wright, et al., 2001). Only 25% reported video game use. In contrast, in the NPR/Kaiser telephone survey in 2000, 82% of all children report using video or computer games, and 35% of all children did so almost daily (Rosenbaum, et al., 2000).

Electronic media use changes with age, and is affected by other demographic characteristics (comprehensively reviewed by Wartella and by Behrman (Behrman, 2000, Wartella, et al., 2000)). Although in 1996 younger children were more likely to report at least weekly computer use (74% of 4th graders compared to 50% of 11th graders), older children used more frequently and reported more daily use (9% of 4th graders compared to 16% of 8th graders and 18% of 11th graders) (National Center for Education Statistics, 1999). Through early childhood, video and computer game use increases with age (Huston, et al., 1999). Computer game use decreases by early adolescence (Buchman and Funk, 1996). In one study, more older children than younger use video games, but there was no age effect on amount of use (Wright, et al., 2001). Over the past several years it appears that total computer time has not increased notably (Tice, 2003).

Girls and boys have similar access to computers, but typically use computers slightly differently (Newberger, 1999, Wright, et al., 2001). Within each age group, boys are significantly more likely to use video games. This sex difference is confirmed in other studies, which also indicate that the content and genre of preferred games differs by sex (Buchman and Funk, 1996).

As with access, income and ethnicity affect use (Rosenbaum, et al., 2000). People with lower incomes have less access, although the disparity is less at school than at home. Lower socioeconomic status (SES) children spend more time with videotapes and TV than higher SES children. Although economic disparities for computer ownership did not change appreciably between 1997 and 2000, the difference in access among children is currently much smaller than that for adults (National Center for Education Statistics, 2005). In households with computers the rates of Internet and computer use are not different between income groups. In the Kaiser Family Foundation survey, the race differences are reversed among computer users: Hispanic and Black children who do have access to computers spend more time at it than White children (109 minutes for Hispanic, 94 for Black and 80 for White) (Roberts, et al., 1999). In 2003, overall White use was 93% and only about 85% for Black and Hispanic children (National Center for Education Statistics, 2005).

In a recent study of 212 children in grades 1-12, computer use was much higher, averaging two hours a day during the week and 2.4 hours a day on the weekend (Burke and Peper, 2002). Total estimated use did not vary with age. In this sample, 71% used TV-based games and 50% used handheld games. Boys used TV-based games significantly more than girls but handheld game use did not differ by gender.

In summary, most children and adolescents in the United States do use computers and electronic games regularly. Although levels are not the same as that for adults computer users who are at risk of work-related upper extremity problems, the overall burden of computer and electronic device use is large. Combined media use estimates approach a working day, with keyboard use alone accounting for up to three hours. Newer technologies may add to the physical load. Curiously, none of the research reviewed here characterizes hand-held game use separately from other games. The recent introduction of small text messaging devices, which can be used everywhere and anytime, may create an additional hand stress that warrants consideration.

1.2.2. Musculoskeletal Symptoms Rates

Baseline symptoms rates must be taken into account when planning and analyzing studies of association between exposures and symptoms. Clinical musculoskeletal syndromes in children are rare in the absence of structural abnormalities, trauma or obvious excessive use such as competitive sports or dance performance. (Al-Qattan, et al., 1996, Malleson and Clinch, 2003, Markison, 1990, Perrin et al., 1989, Shepherd, 1999). Low back pain, which has been investigated extensively, is seen in about 15-20% of adolescents every year (Balagué, et al., 1999, Gunzburg, et al., 1999, Harreby, et al., 1999, Olsen, et al., 1992, Phélip, 1999). Cumulative lifetime rates have been reported as high as 63% in a sample of Norwegian 15-year-olds (Kristensen, et al., 2001).

Research on the overall rate of musculoskeletal pain in the general population of children and adolescents has produced widely varying estimates. In a recent Canadian study, incident neck or upper extremity pain occurring at least weekly in the past six months was reported by 28.4% of high school students surveyed; the baseline prevalence was 31.9%. In Finland, 32.1% of children reported weekly musculoskeletal pain not due to injuries (Mikkelsson, et al., 1998). This pain persisted for year in 54% of study participants (El-Metwally, et al., 2004). Persistence predicted recurrence at four years.

A US review of the literature described estimates of 5%-20% for weekly musculoskeletal pain (Egger, et al., 1999). In this large study, designed to measure psychological correlates of physical symptoms in preadolescents and adolescents, musculoskeletal pain was reported by only 2.2% in a southeastern US sample. This estimate is low compared with most other research, perhaps because cases were defined quite strictly as those experiencing symptoms more than 3 times per week for the past three months, a relatively high level of severity.

Bru asked his 8th grade Norwegian subjects about muscle tension, lower back pain and neck or shoulder pain; 9.5% report at least one severe musculoskeletal symptom (Bru, et al., 1998). Neck or shoulder pain was reported by more than 40%, with 13% reporting moderate or severe complaints. Perquin and others found that pain is a common experience in their survey population of more than 5,000 children in the Netherlands (Perquin et al., 2000): 53.7% of all of all children aged 0 to 18 experienced pain in the previous three months, with 25% having symptoms lasting more than three months according to parent or self reports. Among older children and adolescents (8-18 years), about 15% of girls and 7% of boys reported severe chronic pain. Evaluating 1,000 clinic visits in an urban general practice in Spain, de Inocencio found that 6.1% were attributable to musculoskeletal complaints related to trauma (30%), developmental problems (18%) and overuse syndromes (28%) (1998).

Generally, girls report more symptoms than boys do, and symptoms increase with age (Grimmer and Williams, 2000, Rhee, 2003). Symptoms reporting may differ by ethnicity, with minority group members reporting higher or lower symptoms depending on the area (Rhee, 2003). They may also report more generalized symptoms (Allison, et al., 2002). Finally, having family members who report pain is thought by many to play a role in reporting physical symptoms (Balague, et al., 1994, Osborne, et al., 1989). Other recent literature suggests that parental pain is not a consistent predictor of child pain reporting (Feldman, 1998, Jones, et al., 2004, Kovacs, et al., 2003).

Thus, musculoskeletal pain is common in children and adolescents, although as yet tendonitis, neuropathies and other clinical syndromes are not. Because pain is commonly reported by children and adolescents, it may be difficult to identify an increase in symptoms related to computer or electronic game use unless the difference in symptoms rates between frequent users and less frequent users is quite large.

1.2.3. Computer workstation characteristics

The setting, as well as the duration and frequency of computer use, is important in characterizing risk. This area of research typically has focused on workstation and computer interface design, and especially on classroom furniture. An extensive literature has been produced about school furniture in the past 10 years by researchers around the world. Mismatches between schoolroom furniture and children have been shown in the height and design of desks and chairs (Aagaard-Hansen and Storr-Paulsen, 1995, Linton, et al., 1994, Mandal, 1994, Parcells, et al., 1999). The association with physical symptoms is being investigated using the Portable Ergonomic Observation Method (Murphy, et al., 2002); static classroom postures seem to be associated with neck and upper back pain (Murphy, et al., 2004). The interested reader should refer to a review by Yeats (Yeats, 1997), as well as additional research and policy articles, e.g. (Cho, 1994, Hibaru, 1994, Knight and Noyes, 1999, Marschall, et al., 1995, Noro, 1994, Smith, 2001, Soares, 1991, Tortosa, 1994, Troussier et al, 1999).

Much less has been published about computer workstations for children. Available evidence suggests that, like schoolroom furniture, typical computer workstations at school are not well suited to most children. Concern about the physical demands of computers used at school was expressed as early as 1980 by French researchers who evaluated the impact of VDT use on fatigue in technical high school students (Cantineau et al., 1980). The team also evaluated visual fatigue (Guilbert, et al., 1980, Hache and Francois, 1980). No effect was identified except in some students with existing visual problems. Despite their lack of findings, due in part to their small sample sizes and short exposure times, Cantineau warned that younger children, and especially those most enthusiastic about use, may still be at risk of adverse physical effects from computer use (Cantineau, et al., 1980).

In the past decade, research teams in many countries have described similar concerns. In 1997, the Fifth International Scientific Conference on Work with Display Units in Tokyo included seven papers on children’s use of computers or screen devices. Knave reported that the rapid increasing use of computers in schools had not let to evidence of related musculoskeletal disorders (Knave, 1997). Researchers in Sweden, Japan and Italy announced a project to evaluate how computers are used in schools and whether ergonomic concepts are considered (Bergqvist, et al., 1997). The survey was distributed to administrators in school districts around the world, including the United States; results are not yet available. Jonnson discussed Swedish work regulations and their relationship to computer use at school (Jonnson, 1997), and Johansson and others described a project to address the school computer work environment, including the integration of multimedia (Johansson, et al., 1997). Three papers, described below, explored the visual effects of computer use. As reported by Saito (Saito, et al., 2000), extensive Japanese research activities also include classroom workstation analysis and furniture.

Researchers have documented that children typically do not fit available workstations at school. Using a modified RULA analysis of 95 children aged 8.5-11.5, Oates reported that none of the children were able to use the computer according to accepted postural recommendations (Oates, et al., 1998). The subjects' total RULA scores were either of some concern (61%) or indicated postural risk (39%). The legs, wrist and neck were considered at particular risk, largely because of too-high monitors, keyboards and chairs. Oates compared observed workstation dimensions to those recommended by Wilson (Wilson, 1991), finding that no school workstations could be considered adequate.

It must be noted that Wilson's guidelines were based on monitor height and postural recommendations that may be somewhat outdated, as well as anthropometric data produced more than thirty years ago. This does not negate Oates' findings, and may in fact give them more weight. For example, setting the monitor center at eye level is generally accepted to be too high (Burgess-Limerick, et al., 2000, Turville, et al., 1998), which means that Wilson's conversions to children's dimensions are probably not correct. Thus the workstations observed by Oates may be even farther from ideal.

A dissertation study of 1063 workstations in 14 public schools also showed that sound ergonomic principles were not integrated into school computer classroom design and furniture selection (Brown, 1992). The researcher found that all keyboards and monitors were too high, and no equipment was adjustable. Other parameters of seating and workspace met guidelines at some grade levels. Like Wilson, Brown relied on possibly outdated sources to establish acceptable standards and develop recommendations, suggesting that the problems may be worse than he reports.

Noro and others reported a “huge mismatch” between children and available workstations: tables and chairs are too big, and input devices do not match hand and arm sizes (Noro, et al., 1997). They also pointed out that the human factors dimension is also a bad match: in school computer use, children often share a monitor and CPU, yet there is no attempt to use multiple control devices or adjust the workstation. (The teacher’s need to view the child’s screen without strain is also important. This relates to Williams’ concerns about computer-related pain symptoms experienced by teachers (Williams, 2001).)

A small study in a laboratory setting provided evidence that changing the keyboard angle improves RULA scores and encourages 6th and 8th grade children to work longer at a typing task (Laeser, et al., 1998). Research on muscle activity indicated that posture required by standard computer setup is demanding, and that the demands can be decreased by adapting schoolroom furniture (Straker, et al., 2002).

Australian researchers have shown that students using laptops maintained potentially stressful postures (Harris and Straker, 2000). Only 34% of laptop time was spent at a desk. Other postures described included lying prone, sitting on the floor and sitting with the computer in the lap. In related research, an investigation of the relationship between psychosocial and physical factors in the classroom revealed a potentially complex association among computer and workspace factors and psychosocial factors such as task orientation (Zandvliet and Straker, 2001).

The ergonomic demands of computer use are probably even greater at home, where computers used by the whole family are set up in conditions not optimal for adults and without consideration for smaller people. Children sit unsupported, with feet dangling, necks tilted to view monitors too high for most adults, reaching out and up for pointing devices and keyboards. And home is where children spend most of their computer time as well as use electronic games.

The postural demands on children are not solely due to new technologies. Television viewing is thought to contribute to low back pain (Gunzburg, et al., 1999), and reading may be associated with increased strain on the neck and upper back (Briggs, et al., 2004). Any comprehensive assessment of musculoskeletal demands will need to take a range of activities into account.

Based on this literature, and on most observations, children and adolescents are not using computers in ideal circumstances. However, little is known about the ecology of use in these settings, such as how often children take breaks or what variety of postures they adopt. Evidence about the ergonomic demands of other electronic device use is not found in the literature, except for visual demands research which assesses small game sets as well as computers (Miyao, et al., 1997, Saito, et al., 2000, Sakata, et al., 1997).

1.2.4. Health effects of computer and electronic games use

The question remains, what impact do the observed use patterns and postural demands have on the musculoskeletal health and development of young users of computers and electronic devices?

In 1998, the U.S. Consumer Product Safety Commission reported that almost 10,000 emergency room visits were attributable to computers (equipment and electronic games); half of these events involved people under 24 (Consumer Product Safety Commission, 1998). Whether these were acute or chronic problems is not clear.

Computers might produce visual, cognitive, neurological, behavioral or physical changes in developing children. The variety of behavioral and cognitive changes currently being investigated have been extensively reported on and reviewed (Shields and Behrman, 2000, Wartella, et al., 2000). The potentially positive impact of computer use on cognitive and neuromotor functioning has drawn particular interest recently, for example in studies suggesting a benefit from specific types of computer games to hand-eye coordination as tested by computer use (Green and Bavelier, 2003) or computers used in health education (Griffiths, 2005). Because of the very different issues addressed by this literature, the current discussion will be limited to physical rather than cognitive or psychological effects.

Contact stress

Blisters caused by control devices have been reported (Wood, 2001) and in 2000 led to a settlement between Nintendo and the New York state attorney general requiring the company to provide protective gloves to users of one product version (Department of Law, 2000, Nintendo, 2000).

Systemic health effects

Epileptic seizures were probably the earliest health effect attributed to computer game use (Hart, 1990, Kasteleijn-Nolst Trenite, et al., 1999). Video games are not thought to cause epilepsy but can initiate seizures in a vulnerable subpopulation of epileptics. Video game use, like television viewing, may be associated with excess weight (Robinson, 1999). Other effects potentially linked to computer use include nausea, headache, fatigue and fever seen in a set of heavy game computer users in Japan (Tazawa, et al., 1997). None of this research establishes that computers cause significant health risks. In contrast, Segal measured cardiac and metabolism responses, similar to the effects of mild exercise, in children using video games. The changes were not enough to suggest any health advantage (Segal and Dietz, 1991).

Vision

Visual demands such as reading at young ages are thought to contribute to myopia (Angle and Wissmann, 1978, Parssinen and Lyyra, 1993, Peckham, et al., 1977, Teasdale, et al., 1988). Could computer use have a similar effect? Based on research indicating that virtual reality viewing leads to visual disturbance in adults, Rushton and Riddell posit that early exposure may adversely influence the development of the visual system in children (Rushton and Riddell, 1999) The visual demand of computer use may be greatest in countries with complex written characters (Saito, et al., 2000). Researchers in Japan have shown that children's vision is affected by electronic game use. The blurry target of small handheld games produced a greater accommodative load than larger computer screens or cartoon drawings (Sakata, et al., 1997). Although this study of young children was too short to demonstrate a persistent effect, the authors speculate that this exposure may lead to myopia. Miyao and others demonstrated transient changes in accommodation and increases in myopia with video game play in older children (Miyao, et al., 1997). Marumoto and others observed that increased neck flexion reduces viewing distance and possibly contributes to deficits in accommodation; they believe that their findings are relevant to computer monitor use as well as the reading task they measure (Marumoto, et al., 1999).

Musculoskeletal disorders and symptoms

A growing body of evidence implicates school furniture size and design in back pain and other symptoms in children (Limon, et al., 2004, Linton, et al., 1994, Mandal, 1994, Marschall, et al., 1995, Parcells, et al., 1999, Yeats, 1997). Because computers invite sustained postures and intense concentration, the demands related to inadequate design, limited adjustability and lack of training may be greater than in other classroom activities. The most immediate impact is likely to be strain and pain in soft tissues, which can be early precursors of serious health problems such as tendonitis and carpal tunnel syndrome.

Recent articles and professional discussions indicate that heavy computer users risk repetitive strain in late adolescence and early adulthood. Musculoskeletal problems that affected career plans were reported in college journalism students almost ten years ago (Jackson, 1992). The next report was an informal survey paper published on the internet supports this concern: students showed high rates of pain they attributed to computer use, however the association with time spent on a computer was not significant (Peper and Gibney, 2000).

In a survey of 1601 college seniors, increasing time spent on the computer was significantly associated with increased reporting of musculoskeletal pain and clinical syndromes (p value for trend =0.0001) (Katz, et al., 2000). Students reporting more than 20 hours weekly computer use were 40% more likely to experience symptoms (Odds ratio = 1.4, 95% CI=1.1-1.9). As is typical in this literature, women were more likely than men to report symptoms. Fifty-three percent of all students reported some computer-related symptoms. In a similar study, 42% of college-aged subjects report computer-related pain or discomfort; most of these reported some associated functional limitation. The study was not designed to show associations with predictive factors (Hupert, et al., 2004)

Little is known about the epidemiological or physical ergonomics relating to younger people who use computers or other devices. In early discussions of this topic, it was stated that despite concerns no pattern of symptoms related to computer use had been observed (Knave, 1990, Knave, 1997, Sotoyama, et al., 2002). This has changed. In the Harris paper described earlier, 60% percent of subjects reported discomfort using or carrying their laptop computers (Harris and Straker, 2000). Significant relationships between symptoms and exposures were found only for type of laptop (symptoms experienced while carrying), school location (also while carrying) and school year (level of symptoms), not for maximum or mean daily use.

Straker reported results from a related study comparing symptoms experienced by children while reading, writing, using a laptop computer, using a desktop computer and watching television (Straker, 2001). One group of children (age 11) rarely used computers and the other (age 12) used laptops throughout their school curriculum. 82% of the laptop group reported discomfort associated with laptop use, more twice the rate for reading or for desktop computer use in either age group. No statistical association with use is reported. In the same paper, Straker described motion analysis and EMG research investigating postural demands in computer use and reading. Early results indicate that different media use causes distinct physical stress, but the musculoskeletal risks have not yet been evaluated.

In a longitudinal study of 287 Belgian schoolchildren evaluated at age 9 and age 11, Spalski and colleagues found that daily duration of computer games playing was associated with the development of low back pain (crude OR = 1.5, $p < .1$), but the relationship did not hold when multivariate analysis included additional predictor variables (Szpalski, et al., 2002).

Physicians in Japan have described 19 patients with musculoskeletal symptoms they attribute to "excessive playing of home computer games" (Tazawa, et al., 1997). Trapezius stiffness and elevated scapula, on the non-dominant side, were common in this group. Elimination of computer games resolved symptoms in all patients.

Children also spend large amounts of time using hand-held games, video games or text messaging. As yet, no formal research has evaluated the musculoskeletal impact of electronic games or other electronic devices on school-aged children and adolescents. These activities may differ in their effects on children because of different postural demands, use habits or even cognitive or behavioral effects.

Physicians quoted in the popular press attribute musculoskeletal disorders in their pediatric population to electronic games, but the musculoskeletal effects of video games have not been extensively investigated. Individual case reports of tendonitis caused by game use have been reported in the medical literature, in adults (Brasington, 1990, Reinstein, 1983) as well as children (Bright and Bringhurst, 1992, Cleary, et al., 2002, Cordes and Miller, 2001, Macgregor, 2000, Siegel, 1991). Perhaps the most striking is also the most recent: Cleary described a severe case of hand-arm vibration syndrome has been described in a 15-year old Playstation™ user. Earlier, Macgregor reported an eleven-year-old patient who developed severe pain in his left (dominant) hand and arm between getting a video game at Christmas and returning to school in January. Symptoms resolved completely when he took a week off the game.

Although the available evidence is anecdotal, the widespread recognition of the phrases "Nintendo thumb" and nintendinitis in the world of electronic games provides support for the suspicion that pain symptoms attributable to game use are common. The South Africa Medical Association published a letter on the growing problem written by a 13-year-old girl who had interviewed 120 schoolmates about problems they experienced (Karim, 2005). The medical world may have been slow to recognize the phenomenon but the people who use the equipment seem to know it well.

Several more recent papers used methods similar to those used in the current study to evaluate the relationship between computer use characteristics and musculoskeletal symptoms reporting. In a 6^{th}-grade classroom survey, a small unadjusted correlation between hours of computer use and a composite musculoskeletal discomfort score was reported (Pearson’s r=0.19, p=0.05) (Jacobs and Baker, 2002). In a survey of high school business classes, 28% of 382 respondents reported hand discomfort. The unadjusted odds of reporting neck or back pain were significantly higher in those reporting more than 2 hours daily computer use (Jones and Orr, 1998). As gender was associated both with use and symptoms reporting, and most of the students also reported work-related exposures, the lack of adjustment makes interpretation of these results difficult. When 212 children (grades 1-12, mean age 12 years), interviewed by college-aged siblings, were asked about symptoms occurring “following, during or immediately after your computer/computer game use,” back discomfort was significantly higher in the highest category of game use time (Burke and Peper, 2002). Wrist and back discomfort were associated with computer game play and joystick use, among several other predominantly psychosocial factors. The finding was rendered somewhat less compelling by the use of backward stepwise logistic regression with many potential predictor variables to analyze this data, increasing the chance of finding a significant association of some type. In addition, no adjustment for age or gender was described.

Thus, the literature on children's use of computers suggests there may be an association between use and symptoms, supporting but not establishing the associations shown in this paper.

Related ergonomics evidence also supports the need for further research: Television and TV video game use has been implicated in back pain in children, with game use a more significant factor (Gunzburg, et al., 1999). Because computers and games seem to encourage more sustained postures and intense concentration than TV watching or schoolwork, the strain related to their use may be greater than in other activities.

It has been recognized that some adverse effects of computer or game use might stem from the displacement of other healthier activities (Segal and Dietz, 1991, Subrahmanyam, et al., 2000). Increasing computer use occurs along with a secular trend of less physical activity and decreasing physical education in school, and these trends are replicated in children as they get older (Allison and Adlaf, 1997, Anderssen et al., 1996, DiNubile, 1993, Myers, et al., 1996). However, in some studies the frequency of these activities does not suggest that computer use displaces other physical activity (Feldman, et al., 2003). Thus, the relative effects of changes in physical activity and computer use may be difficult to characterize.

1.2.5. Preventive Measures

Children using these adult tools are provided with few of the protections against injury that are required at work. Chairs and tables may be scaled to the general age of the students, but they are rarely adjustable (Brown, 1992, Noro, et al., 1997, Oates et al., 1998). Keyboards and copy are not positioned with ergonomic considerations in mind. Although some modified keyboard and pointing devices are available, the ergonomic evidence supporting them has not been reported and they are not widely used. Children are not taught the appropriate postures to reduce musculoskeletal and visual strain. Breaks and exercises are not required. Even the extensive guidelines on technology in schools developed by teachers' organizations and the Office of Educational Technology of the U.S. Department of Education do not address ergonomics (International Society for Technology in Education (ISTE), 2000).

A major problem for researchers as well as educators and parents is that there is no accepted standard for how children's workstations should be set up, what work/rest cycles they should follow or what equipment should be modified for their use. An early attempt to provide guidance for setting up computer workstations was produced in 1991 (Wilson, 1991); some of its limitations are discussed above. Other recommendations are available on the Web (Barrero and Hedge, 2000, Ergonomics Society, 2001, Williams (no date)). The children's ergonomics subcommittee of the

International Ergonomics Association is exploring a consensus process to develop consistent guidelines, most recently described at the 4th International Cyberspace Conference on Ergonomics (Straker, 2005). These guidelines are well grounded in current ergonomic knowledge as derived from adults, extrapolated to children at various ages.

Unfortunately, some popular advice sites are produced without a sound understanding of ergonomics, and some promote exercises or equipment without apparent research support. None is yet based on child-specific epidemiology or intervention research. An additional problem is that most available anthropometrical data does not reflect the US population, although newer data is being collected in other countries and has been masterfully catalogued by Norris and Wilson (Norris and Wilson, 1995, Steenbekkers, 1995).

Several research groups have begun intervention studies in classrooms (Jacobs and Baker, 2002, Shinn, et al., 2002, Williams and Jacobs, 2002). Bennett describes a project to retrofit classrooms and provide training for teachers, administrators, computer technicians, students and parents (Bennett, 2001). Hedge reports on the Get Techfit project which focuses on the role of students in the evaluation and correction of ergonomics hazards (Hedge, et al., 2000). Johansson announced a similar project using interactive media (Johansson, et al., 1997). The need to involve students as field ergonomists is a theme in all this work. However, no controlled intervention comparing musculoskeletal symptoms in intervention and control groups has been reported on. Until baseline measures of risk have been established, evaluating the impact of ergonomics interventions will be difficult.

Chapter 2 Study objectives

2.1. Problem statement

Given the current research results relating computer use to musculoskeletal symptoms and syndromes in adults, it is clearly possible that computer and electronic game use poses musculoskeletal risks for young users. Case reports of game-related tendonitis and ergonomic analyses of classroom computers suggest that concern is warranted. With the expansion of the Internet and home computer use, any problems caused by computers can be expected to accelerate in the next few years, as they have in the workplace following the introduction of computers. However no published research has established a compelling and significant association between computer use and clinical syndromes in children or adolescents. No posture, frequency or duration of use has been identified that poses a clear risk or, conversely, can be accepted as safe.

2.2. Research questions

The purpose of this research was to investigate the relationship between computer and electronic game use frequency, duration and posture and the occurrence of musculoskeletal symptoms in children and adolescents aged 12-18. It was designed to explore the following questions:

- Does the use of computers and other electronic devices contribute to the development of musculoskeletal symptoms in children and adolescents?

∉# If so, how big is the impact?

∉# Is there any activity, use pattern or personal characteristic that aggravates or protects against musculoskeletal symptoms or mitigates the effects of computer use?

2.3. Hypotheses

1. Children who use computers and electronic devices more frequently will experience higher rates of neck or upper extremity musculoskeletal symptoms than children who use them less or not at all
2. Children who use computers and electronic devices for longer periods will experience higher rates of neck or upper extremity musculoskeletal symptoms than children who use them less or not at all.
3. Children who use computers and electronic devices in more awkward or uncomfortable postures will experience higher rates of neck or upper extremity musculoskeletal symptoms than children who use them in neutral postures.

Because age, gender and race are associated with pain reporting and with computer and electronic game use, the role of these demographics factors will need to be assessed. In addition, physical activity, which is associated with demographic characteristics (Gordon-Larsen, et al., 1999, Myers, et al., 1996) and perhaps with computer and electronic game use (Feldman, et al., 2003, Marshall, et al., 2004), might be expected to increase (Kujala, et al., 1999, Salminen, et al., 1993) or possibly decrease (Kujala, et al., 1999, Siivola, et al., 2004) symptoms reporting. It is thus also considered as a potential confounder or effect modifier. Because of the complex relationships between these factors, no specific hypothesis about the direction of the effect of exercise or demographics factors was established *a priori*.

Chapter 3 Study methods

3.1. Study design considerations

This study measured the frequency, duration and postural characteristics of adolescents' use of computers and electronic games, assessed the location, intensity and frequency of musculoskeletal symptoms in this population, and explored the associations between electronic device use and musculoskeletal symptoms.

3.1.1. Cross-sectional design

A cross-sectional survey design was selected as the most efficient way to identify these associations. The outcome measure was symptoms prevalence in the past month, and exposures were defined as current normal activity levels. Cross-sectional studies pose a wide range of problems, including using prevalent rather than incident cases, unequal representation of cases compared to non-symptomatic respondents, time effects on reporting of symptoms or exposures and inadequate numbers of cases or of exposed subjects (Hudson, et al., 2005). Overall, the limitations associated with a cross-sectional survey are minimized here. Prevalence as measured over the past month should be similar to cumulative incidence in that period, as in this group symptoms are likely to of limited duration rather than persist permanently. Subject selection was unlikely to be affected by either health or exposure status, as whole classrooms were surveyed rather than a self-selected portion, and the refusal rate was very low. The health endpoint is not serious enough to affect school attendance or otherwise eliminate subjects from the sampling pool. Both exposures and symptoms are common and enough cases are identified in this size of sample.

A survey rather than an interview or observation method was selected because the cost and logistics of interviewing an adequate number of subjects was beyond the means of this project. Observation, in addition to being costly and time-consuming, is logistically difficult to design and to carry out. The limitation of the survey is that the study consists only of self-reported data. Self-report and survey methods have been criticized as unreliable ways of determining exposure or outcome (van der Beek and Frings-Dresen, 1998). Other research has shown low to moderate reliability and validity when comparing observed and self-reported past work activity by adults (Innes and Straker, 1999, Innes and Straker, 1999, Torgen, et al., 1999). Adult reporting of sports or physical activity is described as showing "reasonable validity," but this decays as year pass (Bowles, et al., 2004). Children can provide consistent estimates of activity when referring to the recent past (Aaron et al., 1995, Crocker et al., 1997, Young et al., 1995). Because the time frame for reporting symptoms and exposures is short (one month and current, respectively), recall bias should be minimal. In addition, the efficiency of self-report relative to observation in gathering large amounts of information is a prime consideration in an epidemiological study of this type.

In the case of subclinical musculoskeletal symptoms, there is no accepted objective measure of outcome. Self-report may be the only way to gain access to information about subjects' experience. Children after age ten or eleven are capable of answering questions about physical symptoms (Champion, 1998) and disability (Young et al., 1995) as well as sports activity with moderate reliability and to some extent validly (Aaron et al., 1995, Crocker et al., 1997, Young et al., 1995), which is why the lower age limit of twelve was set for this study.

Several alternative approaches were considered to assess this relationship. A prospective study of symptoms incidence compared to cumulative exposure would provide the strongest model of causality. Such a study would require funding and time not available to the current project. An intervention study that attempted to produce a difference in symptoms by experimentally varying the exposure conditions would have been premature at this point, as the parameters of computer and game use that may be associated with symptoms development have not been characterized in this population. In addition, effectively fixing computer use through group assignment is likely to prove very difficult.

3.1.2. Survey content

Question content was drawn from three research areas: occupational ergonomics, physical activity and pain reporting in children. Occupational ergonomics research provided guidance on the basic format of questions and on the risk factors to target. This research typically measures the presence of symptoms in defined body parts (Baron, 1996, Beaton, et al., 2001, Dickinson, 1995, Katz, et al., 2000, Kumar, 2001, Laubli et al., 1991), the frequency and duration of exposure to ergonomic risk factors in working adults (Bernard, 1997, National Research Council and Institute of

Medicine, 2001, Punnett and van der Beek, 2000), and the relationship between the exposure and the physical symptoms. Physical activity research about how children and adolescents report on the frequency and duration of activity (Booth, 2000, Champion, 1998) provided support for the methodology. The ability of children to provide self-reported information on symptoms, and the methods used to record pain, were evaluated through a review of clinical and research literature (Champion 1998; NCNR 1994; RCNI 1999).

Measuring exposure to ergonomics risk factors

Exposure to computers has been defined in several ways, typically as postural demands, use frequency, and use duration. The specific association with musculoskeletal symptoms reporting in adults has been uneven, at best. Assessing ergonomics hazards is particularly complex as the impact varies greatly depending on the combination of frequency, duration and cumulative time of exposure, as well as rest and personal characteristics (Punnett and van der Beek, 2000). Combining different activities into an exposure scale erases the differential impact of exposure variables, whereas using too many predictor variables attenuates analytic power.

Some researchers in this area cast a wide net for exposure variables, then try to winnow the exposures to those most significant in predicting outcomes on their database. In a recent study of factors potentially influencing musculoskeletal symptoms reporting in children using electronic devices, researchers measured 22 variables then used stepwise regression to identify those that were significantly associated with symptoms reporting (Burke and Peper, 2002). Exploratory research of multiple variables can be useful in generating hypotheses and indicating directions for future research, when done in the context of factorial analysis and blocked stepwise regression based on theory or on factors generated. Otherwise this scattershot approach can be criticized for forcing support for relationships not grounded in theory, and for ignoring the results of multiple, post hoc testing.

Researchers have separated types of activity, for example distinguishing between web surfing, school work, and games used on the computer or even kinds of games (e.g. Burke and Peper, 2002). The theoretical rationale for distinguishing or combining these uses in risk categories is not well established – for example, would writing in a role-play game on the computer be more like school work or surfing or even TV-based role-play games? In pilot studies of earlier drafts of the CAUTS (Child and Adolescent Use of Technology and Symptoms) survey, many respondents left questions about types of use blank, making assessing relative exposure impossible. Therefore no attempt was made to distinguish use types.

To keep the contributing variables assessed to a parsimonious level, this survey focused on the main electronic activities that might affect musculoskeletal health in children and adolescents: computer use at school and at home, hand-held game use, and TV-based game use. These were all proposed to increase symptoms reporting in the neck and upper extremities. The questions were designed to measure specified, non-overlapping exposures that adequately represent the likely contributors, then to test them individually and in combination.

Parsimony came at some cost of sensitivity. The study did not assess the complex of psychological or cognitive aspects of computer use. Although these are likely to be important in predicting symptoms reporting (Rhee, 2003), the model and the methods for measuring and assessing these factors in this population, and associating them with musculoskeletal demands, are not yet well developed. In a further attempt to reduce the length and difficulty of the survey, it did not measure the varied specific demands on young people involved in competitive sports, dance or music involvement, asking only about overall exercise level. Finally, the important demands of text messaging on cell phones and other hand-held text devices was not evaluated largely because these exposures became notable in this population only after the instrument was developed.

Postures

Self-report of postures is particularly problematic. Although some researchers have developed tools for using self-report to record posture in adult workers, the agreement with observation is typically only moderate, and depends on the posture under consideration (Torgen, et al., 1999). In field trials of the current survey (referred to hereafter as the CAUTS survey, subjects were unable to report postures consistent with concurrent expert observation (described in Appendix B). Given these limitations it was decided to ask respondents to select an image of a computer workstation that best matched their own. The levels of biomechanical demand the equipment configurations were thought to reflect are described in section 3.1.4 below.

Symptoms self-report

A symptoms survey used in occupational epidemiology typically includes a body map, usually front and back gender-neutral drawings and questions about symptoms frequency, intensity and sometimes duration. The Cornell Musculoskeletal Discomfort Questionnaire (NMQ) produced by the Human Factors and Ergonomics Laboratory is a standard example, adapted from the NIOSH symptoms survey (Hedge, et al., 1999). This is the format used in this study.

Self-reported symptoms surveys are problematic for several reasons. They are not well-validated using objective measures of diagnosis or disability. Response bias may affect the apparent prevalence of symptoms if symptomatic people are willing to participate more or less than those without symptoms. Finally, both reliability and validity vary with the conditions and populations in which they are used. As Katz et al. (2000) comment, “sensitivity and specificity of classification criteria vary according to the spectrum of disease in the sample study.”

In support of self-report, Baron, Hales and Hurrell (1996) evaluated the occupational application of the Nordic musculoskeletal questionnaire and the NIOSH symptoms survey, which are similar to the body map and pain frequency and duration scales used in the current study. The NIOSH symptoms questionnaire was about 70% specific in adult workers when compared to a medical exam; sensitivity depended on the case definition (Baron, 1996). The NMQ is consistent in test-retest reliability (less than 25 percent disagreement within one to two weeks). In general, reported symptoms are higher if the survey is carried out in the context of a work complaint or investigation, suggesting that caution is necessary when comparing different studies of symptoms prevalence. Adult low back pain sufferers are able to estimate an average pain in the past week that is consistent with daily records (Bolton, 1999). Differential misclassification of exposure related to symptoms presence or absence was not seen in a validation study of workers reporting past work postures and times (Torgen, et al., 1999).

There is a question of at what level of detail symptoms should be evaluated. Pain reporting in a sample of workers showed a pattern of localization into neck/shoulder, back/low back, right arm/hand and left arm/hand regions; the authors suggested that they be analyzed in this pattern (Laubli et al., 1991). Shoulder symptoms also correlate with arm symptoms. Others support this recommendation for a regional outcome measure in clinical work (Beaton, et al., 2001, Davis, et al., 1999) rather than disease or joint-specific tools. Research on computers and office work suggest that groups of symptoms rather than specific diagnoses or locations should be assessed (Devereux, et al., 2002, Gerr, et al., 2004, Marcus, et al., 2002).

Researchers have typically asked subjects about symptoms related to or occurring during or following computer use (e.g. (Hamilton, et al., 2005, Katz, et al., 2000, Peper and Gibney, 2000)). But while general symptoms questions run the risk of including problems not related to computer use, limiting the question to computer-related symptoms might lead subjects to make conclusions about their exposures or symptoms. It was decided in this case to separate the symptoms questions as much as possible from the potential causes. Thus subjects were not asked to describe symptoms related to computer use, but only to report the occurrence whatever the cause.

In another section, subjects provided open-ended responses about what they thought caused the symptoms. The problem with asking subjects to assign causes to the symptoms is similar to the problem of asking about symptoms that occur during or after computer use. It is possible that asking specifically about computer-related symptoms will encourage heavier computer users to assess their symptoms differently than others do. This approach seems likely to elicit increased symptoms reporting among those who are aware that computer use may be a problem. In any case, people often do not know what caused their symptoms. The actual cause of symptoms is not necessarily the same as the activity in which symptoms are most noticed. Thus cause questions were asked after the exposure and symptoms items were completed.

3.1.3. Children as reporters of symptoms and exposures

In children, self-reporting is complicated by the varied abilities of the respondents to recall or record symptoms or exposures. The proposed study attempts to reduce the problems by surveying children and adolescents older than 12. The literature indicates that children and adolescents at these ages can read and understand survey questions and make fairly reliable estimates of symptoms and exposures.

Measuring physical activity by children

Children's activity is particularly difficult to measure because it tends to be more sporadic and varied than that of adults. They don't sit quietly, and they don't exercise single-mindedly (Welk, et al., 2000). Despite this, and despite problems related to seasonal variability in activity (Rifas-Shiman, et al., 2001), self-report by older children has been widely used in physical activity research. Adolescents (aged 15-18) were capable of using a written survey form to reliably report on average past year physical activity, using a categorical frequency estimate form similar to that used in the proposed study (Aaron et al., 1995). Children above the age of 9 showed good test-retest reliability using the Physical Activity Questionnaire for Older Children (Crocker et al., 1997). The Godin-Shepherd Leisure-Time Exercise Questionnaire was moderately correlated with other standard activity rating scales in 5th, 8th and 11th grade adolescents (Sallis, 1993). Children aged 5 to 15 with musculoskeletal disabilities demonstrate a high inter-rater reliability with parent reports using the Activities Scale for Kids survey (Young et al., 1995), and these results are validated by clinicians' reports (Young, et al., 2000); children over nine years used the survey without a parent's assistance. In summary, children above the elementary grades are capable of reporting on their physical activity consistently. The validity of physical activity reports is not well established in this population; the same problem exists in physical activity research in other groups (Sallis and Saelens, 2000).

Children's self-reported pain symptoms

Most symptoms surveys are tested on hospitalized children or those with chronic disease; acute pain research has also looked at children having a needlestick (RCNI, 1999). Hospitalized children aged 8-17 reliably and validly report pain symptoms using a body map (Savedra et al., 1989), as confirmed by clinical evaluators by observation and medical record. Black children reported somewhat more pain than confirmed by evaluators; whether this was due to overreporting by the subjects or underreporting by evaluators was not explored in the study. In interviews, both chronically ill and healthy children's reporting of the occurrence and intensity pain symptoms agree substantially with parent report (McGrath, 2000). This research on children's pain reporting may not entirely reflect the validity or reliability of these measures in the generally healthy population (Young et al., 1995), especially when reporting on chronic or intermittent symptoms.

There is a debate about whether children's self-report of pain should be done though interview, using visual analogue scales, or verbal rating scales. It has been stated that " Verbally competent children of 12 years or older can use the adult form of the McGill Pain Questionnaire " (Champion, 1998). The verbal rating scale appears to be more sensitive, and children report higher levels of moderate to severe pain using a verbal rather than a visual scale (Tesler, et al., 1991). The Adolescent Pediatric Pain Tool is one of the most widely used methods in this population (NCNR, 1994, RCNI, 1999). The combined body map, verbal rating scale (from no pain to worst possible pain) and descriptive word choice component is thought to be a better format for adolescents (12-20) than the McGill Pain Questionnaire for reporting acute symptoms (Gillies, et al., 1997). The rating scale is reported to have good test-retest reliability in the measurement of stable pain (Van Cleve, 2001, Wilkie, et al., 1990). In summary, the subjects in the proposed study (aged 12-18) are generally considered old enough to provide reliable reports of symptoms in response to questionnaires.

3.1.4. Instrument

The final version of the CAUTS survey is a 71-question, six page form. This survey was developed and tested as described in appendix B.

Twenty-five items addressed the frequency and duration of activities, 11 described the subject's usual computer workstation, 28 covered symptoms frequency, duration and impact, and 7 were demographic items. Appendix C lists the variables measured, along with their type and values.

Although at 6 dense pages the survey seemed long to the outside viewer, all subjects in the field trials completed it within 15 minutes, even low literacy subjects as young as 12 for whom English was not the first language. The survey was measured at a Flesch-Kincaid grade level of 5.2 (Microsoft Word 2000).

Activity questions

Activities are assessed in 5 ordinal categories describing frequency and duration of exposure. Exposure was recorded for computer use at school, computer use at home, game use, television watching, vigorous physical activity and reading.

Computer use did not distinguish between laptop and desktop computers or among types of use. Age at first use of computers and electronic devices was also reported. Exposure questions are similar to those used in occupational health research, asking subjects to estimate typical electronic device use as well as general physical activity and television watching. Each activity was measured in terms of typical frequency, longest time spent without a break, and estimated time spent on typical weekday and weekend day. The time scales were designed to approximate equal time intervals. The responses were categorized rather than marked as times on an open-ended scale, following the example of physical activity researchers (Aaron et al., 1995) and occupational health research indicating that subjects make a wider selection of categories when each level, not simply the endpoints, are characterized clearly (Torgen, et al., 1999).

Equipment

Subjects were asked what electronic device they used most, where they used it and what input and control devices they used.

It was decided to record equipment placement rather than measure reach distance, wrist, arm or neck angle through self-report. In the pilot tests described in Appendix B, subjects were observed as they reported their posture; they were consistently unable to report even single instantaneous postures reliably or validly. As posture can vary dramatically, a single estimate is not likely to prove an adequate measure of risk. Equipment placement, being more consistent for each user, was considered a better indicator of biomechanical strain, despite the recognized limitations described in the discussion.

The computer workstation questions ask subjects to record the placement of their most frequently used electronic device by comparing it to pictures. The resulting 4 postures variables as listed in table 1 are shown with response categories arranged in order of increasing biomechanical demand, with the fourth category neutral, unknown or equivocal. For example, monitor position decreases in demand from higher to lower placement, but a device with the monitor attached to a device could increase the neck demand (as with a laptop) or decrease it (as with a game held up to avoid neck bending).

Table 1. Equipment position postural demands

	Highest	Medium	Least	Neutral or unknown
Monitor position:	on shelf or stand	sitting on computer	directly on table	attached to device
Keyboard position	on table top	on lap	tray lower than table	no keyboard (video game)
Mouse/controller position	on table or desk top	on legs or lap	tray lower than table	on floor
Foot position	not reach ground	varies	easily touch ground	other

The monitor was considered more demanding the higher it was, because increasing height requires increasing neck extension. This is thought to increase demands on the muscles in the upper back and on the cervical spine. The higher keyboard or mouse/controller position was also considered more demanding as this requires the use of upper back muscles to raise the arms, elicits more forward flexion at the shoulder and is likely to result in bent wrists. Feet unsupported or dangling was considered most demanding, as back support is reduced and the user may be more likely to lean on the arm for stability.

Symptoms

Symptoms of pain or discomfort experienced in the past month were reported on a body map as used in occupational ergonomics (Corlett, 1995; Hedge, et al., 1999). In this survey, symptoms were freely marked on a body map then coded by region. Left and right were not distinguished, as in other research subjects younger than 16 were not reliable at correctly differentiating left and right on a body map (Savedra et al., 1989). Dorsal and frontal symptoms were not distinguished, to best collect data on musculoskeletal disorders, as opposed to pain related to illnesses often reported in the stomach or face. In addition, in pilot trials of the survey (described in appendix B) subjects typically marked only one image even if two were provided. Girls were asked not to include pain related to the menstrual cycle.

In an attempt to assess the potential severity of symptoms, in addition to the more straightforward occurrence in a defined period as measured on the body map, frequency and intensity questions were used, similar to those used in the Cornell Musculoskeletal Discomfort Questionnaires (Hedge, et al., 1999). The combined map and scale format was similar to the Adolescent Pediatric Pain Tool (APPT) (Gillies, et al., 1999, Savedra, et al., 1989). The verbal rating scale was simplified from the APPT format by using five word categories instead of an open scale with five word anchors.

Frequency and intensity of symptoms were addressed as 5-category ordinal variables for these areas: neck or upper back; shoulder, arm or elbow; wrist or hand; lower back; hips, legs, feet.

To assess overall impact, respondents were asked to report whether they have changed any activity in response to an experience with pain or discomfort. Subjects were also asked to describe the symptoms' impact and potential cause in open-ended questions.

The reporting of any symptoms in the neck or upper extremity on the body map is the outcome of major interest in this study. The body map data was selected over the frequency and intensity scales largely because the initial hypotheses included prediction about occurrence only rather than quantitative aspects of symptoms. There was no a priori method for defining a positive outcome based on the scales.

Other variables

Demographic variables consisted of race, gender, birth year and month, weight and height in feet and inches. School and grade level (7-8, 9-10 and 11-12) were included as part of the record number. Handedness and use of vision correction were also recorded.

Including SES as a variable in the analysis was considered. However, measurement of SES by self-report is notoriously difficult, especially from children. They may be unable to accurately provide information, although some research suggests that for children in the age group under consideration, agreement with parental report is reasonably good (Lien, et al., 2001). More significantly, subjects have reported finding questions about family financial status onerous and intrusive (Feldman, et al., 2002). Therefore SES was not assessed.

3.1.5. Design concerns

The cross-sectional study design used here is vulnerable to incidence-prevalence bias and prevalence complement ratio bias (Szklo and Nieto, 2000). This means that when using prevalence to estimate the incidence rate ratio, biases result if duration or prevalence of outcome is different in exposed and unexposed populations. When duration of the outcome measure is the same in exposed and unexposed, and prevalence is low, this bias has no impact on the estimate. In the case of upper extremity symptoms, prevalence is probably not low enough to eliminate this bias. If the duration of the outcome is independent of exposure, the cross-sectional design underestimates the strength of association. This highlights the value of using incident cases and a longitudinal design in future studies. All findings from this study design were perforce limited to interpretations of prevalence and odds ratios, and not incidence, risk or causal direction.

Temporal bias, also called reverse causality, may occur if subjects decrease or eliminate computer use after experiencing pain, because a portion of symptomatic subjects may be recorded as unexposed. The survey controls for this by asking if any activities, including the use of electronic devices, have changed as a result of symptoms experienced. This information was used to evaluate the likelihood of such a bias.

Confounders, covariates and effect modifiers

Age, sex and race are known associates both of computer and electronic game use (Buchman and Funk, 1996, Newberger, 1999, Newberger, 2001, Rosenbaum, et al., 2000, Stanger and Gridina, 1999, Woodard and Gridina, 2000, Wright, et al., 2001) and of symptoms reporting (Egger, et al., 1999, Grimmer and Williams, 2000, Malleson et al., 1992, Mikkelsson, et al., 1998, Perquin et al., 2000) (although de Inocencio did not see differences by sex (1998)). Thus, these demographic characteristics were investigated as potential confounders and controlled for in the analysis. Body mass index (Werner, et al., 2005) and exercise (Garrick and Requa, 2003, Kujala, et al., 1999, Roth-Isigkeit, et al., 2005) are potentially associated with upper extremity symptoms. They were evaluated to see if they acted as confounders or effect modifiers. Age and grade level were also assessed as effect modifiers.

Sample size

The target sample size of 500 subjects was derived from the results of the small pilot study (n=44), described in Appendix B. The proportion of students with upper extremity symptoms occurring at least weekly was 14.3% in the group reporting low home computer use and 20% in those reporting high home computer use, defined as every day or almost every day. The proportion in the nonexposed group is similar to estimates for musculoskeletal symptoms in an adolescent population, suggesting that this is a reasonable baseline estimate for sample size calculations.

The sample size estimation method described by Norman and Streiner (2000, page 269) defines the number of subjects needed to identify a change in proportions (p_1-p_2) at Ŭ=.05 with a power of 80% as $n=16(1-p)p/(p_1-p_2)^2$; p is the average of the two proportions, assuming that the number of exposed and unexposed subjects is equal. To identify a change in proportions from 15% in unexposed subject to 22% in exposed subjects the sample size should be 492. To assure adequate power to identify a similar difference in symptoms in both genders, 600 subjects were requested from the school district to make sure nonresponse and other data loss did not weaken the study power. The district provided 636 subjects of whom 476 (75%) returned usable surveys. This sample size was not calculated to take interactions and other subgroup analysis into account.

Distribution methods

Alternate methods of survey distribution were considered, including mailed surveys and online data collection. Mailed survey distribution was not considered likely to result in adequate or unbiased response, as the pilot response rate for mailed consent forms was about 20%, and because those with symptoms and those with more computer exposure might be more likely to respond. On-line response was likely to recruit an untypical sample of those more familiar with computer technology, and with greater access to Internet connections. Thus in-person distribution of the written survey was chosen as the optimal method for reaching a large number of respondents representing the overall population, and for achieving an adequate response rate.

3.2. Recruitment and survey distribution

3.2.1. Study site

The school district of the small Connecticut city was chosen because it was outside the urban concentration of New York City, yet within reasonable travel time for data collection. It was expected to be more heterogenous for race distribution and socioeconomic status (SES) than New York City schools. It was recruited through personal contacts with the school board.

The district contained three middle schools and two high schools, with about 4850 students. The population was heterogeneous for race and SES, according to school board statistics (State of Connecticut, 2002). Overall, the district was somewhat lower in SES indicators than the state average. In 2001 the average annual wage was $23,362 compared to $46,993 statewide and $36,219 nationally (Bureau of Labor Statistics, 2005). Among the nine educational reference groups (ERGs) defined by the state, the school system is ranked in group H, the second lowest. In this district, 61% of 8th grade students read at or above recommended levels, compared to 54% in ERG group H and 66% statewide (Lohman, 2003). SES data at the school or the individual level was not available. As another marker of SES, it was found that the study schools varied in the percent of children eligible for subsidized lunches, compared to each other, to the group H average and the state average (State of Connecticut, 2002). The national rate is 37%. MS2 and MS3 are slightly poorer than the state overall, HS2 is less poor and HS1 and MS1 are about the same as the state average. Thus the district overall is less affluent than the state and the national average, but the students in individual schools may not be.

3.2.2. Subjects

The study group consisted of 636 12-18-year-olds, about 14% of the middle and high school students in the district. Study participants were selected from general education classrooms heterogeneous for academic standing and interests, in all the middle and high schools in the district. The administrative director of the district asked principals from each of the three middle schools and both high schools to provide 125 names for subject recruitment.

Because the intention was to evaluate the characteristics of the general population, rather than focus on special needs or exposures, and to make the written survey practical, all subjects recruited were English-speaking and literate, in general education classrooms, as confirmed by the school principals. Three students required some assistance in filling out the surveys, because of physical or behavioral disabilities, which was provided by their paraprofessional aides.

3.2.3. Recruitment

In the three middle schools, general education homerooms were selected by the principals, who had been requested to produce 125 subjects in each school. No identified rule was used to make the selection. The same procedure was followed for

9th and 10th graders in one high school (HS2). In the other high school (HS1), the principal decided to randomly select 150 subjects from among the 11th and 12th grade students. Each principal provided a list of parent and child names and home addresses. Table 2 shows the numbers of students in each school, the response frequencies and the percentage responses.

Table 2. Survey distribution

	School	HS1	HS2	MS1	MS2	MS3	Total
Students in school (N)		1385	1347	593	554	972	4851
Parent letters sent (N)		150	137	126	106	117	**636**
Refusal (N)	parent	4	1	6	3	0	14
	student	16	8	7	2	0	33
Absent or missing from survey session(N)		54	30	12	0	1	97
Surveys (N)	completed	76	98	101	101	116	**492**
	rejected	10	1	3	0	2	16
	analyzed	66	97	98	101	114	**476**
% of target analyzed		44	71	78	95	97	75
% of population analyzed		5	7	17	18	12	10

The need to procure consent from parents as well as subjects, required by federal regulations for subjects under 18, typically leads to a selection bias (Esbensen and Deschenes, 1996). In particular, racial and economic minority subjects are under-represented when positive parental consent is required (Odonnell and Duran, 1997). To avoid these problems and enhance the response rate, a waiver of full parental consent was obtained. In accordance with New York University regulations on research involving child subjects, informed consent letters were sent to the parents of 636 students. Parents were requested to return a letter only if they wished to refuse consent for participation. Consent forms and recruitment letters are included in Appendix E.

Eleven refusals were received before data collection began, and three after data was entered. These subjects, 2.4% of the original population, were removed from the database. At the time of survey distribution, subjects were also provided with informed consent letters and allowed to decline participation. About 5% (N=33) declined and were provided with crossword puzzles and word games to occupy them while their fellow students filled out the surveys. Although in the current design there was no way to assess the differences in refusers and respondents, the refusing group was very small and was not likely to have influenced the associations observed.

3.2.4. Distribution

Surveys were distributed by the primary investigator and assistants. In four schools it was distributed in homerooms in the presence of the homeroom teacher. In HS1, subjects were issued hall passes and the survey was distributed in a lunchroom, with no school personnel present. Subjects were allowed to take as long as needed, and all finished within twenty minutes. Distribution took place on four days in early January 2003. Altogether 492 surveys were collected, or 77% of the initial study group. Of these, 16 proved to have patently spurious responses (including consistently excessive heights, weights and times, obscene comments and fantastic stories of lost limbs and drug use). As most of these 16 were filled out in clusters in the same school, and by the comments clearly not independent of each other, they were considered unusable data and eliminated from the database, leaving 476 usable surveys. Thus data from 75% of the study sample, or 10% of the entire district middle and high school population, was analyzed.

Participation varied by school. In HS1, only half the students showed up. In addition, 10 of the 16 rejected surveys were from this group, perhaps a result of the absence of school authority, and the refusal rate rate was higher than other schools. Thus only 44% of HS1 subjects provided usable data. In the other schools the useable survey rate ranged from 71% (on a snowy day with high absenteeism) to 97%.

Chapter 4 Data processing and analysis

4.1. Data processing

4.1.1. Data entry and cleaning

All data was entered by the investigator into an Epidata template (Epidata 1.5, 2000, Odense Sweden) using DragonDictate v.3.0 (Dragon Dictate v3.0, Dragonsys, Boston). Single data entry followed by quality checking was employed, as recommended to maximize efficiency and data integrity (Buchele, et al., 2005). Following entry, a sampling of 35 surveys (7.5% of the study subjects) showed that 30% had at least one error in one variable, typically a one-position error in a five-level variable. Each record was then proofread against the original data. About 20 percent of the records required a correction in at least one field of the more than 70 questions, for an approximate question error rate of 1%. A final sampling of 20 records (4% of the subjects) following the corrections showed no errors.

4.1.2. Coding

Body map responses were coded as binomial variables for the eight areas marked on the map: neck; upper back; shoulder; arm or elbow; wrist or hand; midback; lower back; hips, legs, or feet.

Missing data concerning changes in activity, doctor visits and vision correction were coded as “no.” Missing data on symptoms were coded as “no” except where symptoms intensity was marked and symptoms frequency was not marked. In these cases, symptoms frequency was coded as the mean of the frequencies for that location intensity in the database (74 cases, between 1% and 3% for each of the 5 areas). If symptoms intensity and frequency for all body areas were not checked, the variable was left blank.

Data were then exported to SPSS 10.0.5 (SPSS, 1999) for analysis.

4.1.3. Derived variables

Appendix D lists the derived variables, their characteristics and the variables they were developed from.

Demographics

Race was reported as White, Black or African American, Hispanic or Latino, Asian, American Indian/Alaska Native or Other (which included those reporting multiple race). Because there were few non-white respondents, race was collapsed into two categories ("White" and "Nonwhite or multiracial").

Age was calculated from birth month and year variables. For the 13% of subjects who did not report age year, age was imputed as the average of the two proximal survey respondents. This approach was used because the surveys were filled out in grade-based homerooms, thus the students were most likely to born in the same year and on average within six months of each other. Age was entered as a continuous variable in most analyses. Where indicated in the text and tables, Age as a three-level ordinal variable (<=14, >14-16, >16), was used to stratify the analyses. School level and grade level were derived from school identifying information.

In adults, BMI is calculated as the proportion of weight to the square of height (Center for Disease Control, 2005). For children, BMI is expected to differ with age and sex – younger children should be proportionately lighter for their height, while the normal relationship with sex varies across ages. Thus the relevant variable for comparing children is percentile BMI normed for age and gender, which was calculated using Nutstat (Epi Info, 2005). The percentiles of clinical significance are defined as >=85% of the population norm (at risk of overweight, which would be called overweight for adults) and >=95% of the population norm (overweight, which would be called obese in adults). BMI was analyzed here as the overweight category status for gender and age (not at risk of overweight, at risk of overweight, and overweight). Underweight (defined as <5th percentile) was not assessed.

BMI percentile for age and gender is not the best way to assess overweight. Compared to skin-fold measurements, overweight status based on BMI is a specific but not sensitive measure of risk of overweight (Malina and Katzmarzyk, 1999). BMI could also reflect a higher bone or muscle mass: athletes tend to have higher body mass ratios than average despite not having excessive body fat. In addition, the standard 3-level medical ranking (not at risk of overweight, at risk, overweight) does not take the possibly deleterious effects of underweight into account. However, BMI status can be calculated from self-reported data and is the format typically used when screening for overweight in this population.

Weight or height was not provided by 85 respondents, and another 21 respondents did not provide gender. Thus there were a total of 106 for whom BMI for age and sex was impossible to calculate. Five subjects reported weight and height data leading to BMIs of 40 or greater. As the BMI data was otherwise regularly distributed between the lowest calculated (13.4) and 34, and such extremely heavy subjects were not observed in the responding population, these responses were determined to be probably spurious and they were removed from analyses involving BMI, leaving 364 subjects with usable BMI data. Although this reduced the power of analyses involving weight status, including this term did not affect the observed relationships between exposures and outcomes.

Exposure variables

For the exposure frequency variables (e.g. computer use, electronic games, exercise and reading), dichotomous variables for exposure were produced. High frequency was defined as “daily or almost daily” and less frequent as “2-3 days a week or less.” This was based on the expectation that intermittent or infrequent exposure is unlikely to have any measurable effect on musculoskeletal symptoms, which tend to result from the accumulation of microtrauma (Barr, et al., 2003) or from sustained loading without rest (Kumar, 2001). For ease of reading, these exposure categories will be referred to as “daily” and “less frequent” throughout this paper.

Three-level ordinal variables were also produced for all exposure frequency variables (“daily or almost daily,” “2-3 days a week,” and “weekly or less.”). A three level time variable for each exposure was defined based on the estimated hours per day (>=3hrs, 1-2 hrs, <=0.5 hrs). The exposure duration variables were similarly converted to three levels (>=2 hrs, 0.5-1.5 hrs, <0.5 hrs). All the derived time-based variables described were ordinal; the intervals enforced by the question format were not assumed to be proportional.

Years of device use was calculated from age at first use and current age.

Outcome variables produced

Computer ergonomics research in the U.S. typically emphasizes distal outcomes, frequently focusing only on the hands. However, the literature shows that neck and shoulder symptoms are also associated with computer use (Gerr, et al., 2004, Palmer, et al., 2001). Often a single exposure type is associated with multiple pain sites. Thus rather than focusing on separate symptom location, the main outcome in this analysis was the reporting of any neck or upper extremity symptoms. The dichotomous variable “Neck or upper extremities symptoms in the past month” was coded “1” if symptoms were marked on the body map in any combination of the neck, shoulder, arm, wrist or hand, “0” otherwise.

The frequency and intensity variables measured do not provide a complete picture of the symptoms experience when reported separately. To explore the seriousness of the reported symptoms, symptoms severity variables were produced for the areas rated for symptoms frequency and intensity. Each symptoms frequency variable was converted to days per days per month and multiplied by the value of the intensity variable for that area. These were treated as continuous variables.

Symptoms severity in the entire region of neck or upper extremities was calculated as the maximum severity value reported by each subject in the neck or upper back, the wrists or hands and the shoulder, arms or elbows. Thus a person with severe symptoms in one area will have the same score as one with severe symptoms in several areas. A person with severe symptoms in one area will have a higher severity score than a subject with multiple, less severe symptoms.

As noted in the methods sections, subjects were asked to describe the symptoms' impact and potential cause in open-ended questions; only 31 responded to this item. These responses were coded for analysis as one of eight categories: Computer/game, Other ergonomics issue, Sports, dance or exercise, Musical instrument, Postural problems, Health problem/accident, Backpack, or Behavior.

4.2. Statistics

Means differences were assessed using 2-sided independent samples t-test. In these and all other analyses, missing variables were excluded analysis by analysis.

Correlation tests were non-parametric, as the exposure variables were ordinal rather than equal interval (Kiess, 1996, p 461). In addition, because of the consistently skewed character of the sampling distribution (described in the results section), the underlying population distribution cannot be assumed to be normally distributed either for exposures or outcomes. To assess associations among ordinal exposures, Spearman's rank order correlation coefficients are reported. Correlation analyses stratified by gender and age are also described. For dichotomous symptoms variables, Pearson's chi-square and partial Kendall's tau b adjusted for gender, race and age were calculated. Tau b is a measure of association, appropriate for binary variables, that is computed as the excess of concordant over discordant pairs, corrected for ties. There is no clear interpretation of the meaning of this correlation coefficient, but it provides a way of testing for the distribution probability between two dichotomous variables.

Univariate and multivariate unconditional logistic regression analyses were performed for predictors of binary symptoms variables. All variables in multivariate analyses were entered together. Odds ratios were calculated adjusting for age (as a continuous variable), race (White or nonwhite/multiracial) and gender. Categorical variables were entered as simple predictors with the lowest level as the reference category. The odds ratio is the odds of experiencing a specified outcome given an exposure compared to the odds of experiencing the outcome in the absence of exposure. An odds ratio of 1 indicates no association between outcome and exposure, above 1 a positive association and less than 1 a protective association with exposure. If the 95% confidence interval for the odds ratio includes 1 the relationship is not statistically significant at Ŭ=0.05.

Linear regression was used to assess the relationship between exposures and the calculated continuous variables of symptoms severity.

For all tests the probability level for significance was defined as $p<.05$, and 95% confidence intervals for odds ratios are reported.

Chapter 5 Results

This chapter describes the respondent characteristics and response frequency distributions. Correlations among activities, symptoms and demographics are reported. Finally, logistic and linear regression models are developed to test the study hypotheses and answer the research questions.

5.1. Demographics

The study group was similar in demographic characteristics to the school district as a whole, except in age, as shown in table 3.

Table 3. Demographic characteristics distribution by school compared to district and national proportions

Characteristic	N (%)	%	% in School District (2001)	% US <=18
Gender				
Male	212	45		51
Female	224	47		49
Blank	40	8		NA
Race				
White	367	79.4	81.1	67*
Black	20	4.3	6.7	15*
Hispanic	44	9.5	9.8	17*
Asian	5	1.1	.3	3*
Other/multiracial	21	4.5	NA	13*
Blank	14		NA	NA
Age				
12-13	298	62.6	Middle school = 44% (2029)	26**
14-15	91	19.1	High school =	25**
16-19	87	18.3	56% (2589)	49**

*Source: U.S. Census Bureau, Census 2000, special tabulation.
** National Population Estimates, http://www.census.gov/popest/estimates.php

The sample was about evenly split between girls and boys (51% of those completing this question compared to 49%, p=0.6). Gender was not reported by 8% of the sample. A greater proportion of the respondents were white than in the national population, reflecting the race distribution in the community.

Age ranged from 12 years to 19 years. It was not distributed equally throughout the range. The age imbalance is attributable to the uneven survey distribution by school. As illustrated in table 3 earlier, a comparable number of students were recruited from each school, and there were three middle schools and only two high schools. In addition, at the high school contributing the 11th and 12th graders, subjects were provided with hall passes rather than filling out the surveys in homerooms. In the absence of authority, only 50% of this group showed up, and a larger proportion declined to participate than in other schools. Thus, the majority of respondents were in middle schools, and the average age (14) was lower than the midpoint of the range (15.5). This imbalance was not foreseen and thus no oversampling by school or grade was carried out.

The distribution of subjects observed in each category of overweight status as shown in table 4 was compared to the expected using the Chi Square Goodness of Fit test with 2 degrees of freedom. The observed distribution differs significantly from the expected (χ^2=15.6, $p<0.001$). There are notably more overweight subjects than expected, and fewer not at risk of overweight.

Table 4. BMI percentile category for age and gender (n=364)

	<85		85-<95		>=95	
	N	%	N	%	N	%
Observed	289	79.4	41	11.3	34	9.3
Expected	309.4	85	36.4	10	18.2	5

5.2. Response frequency distributions

5.2.1. Exposure measures

Activity frequency

Table 5 shows the reported activity frequencies. The answer categories on the survey were daily or almost daily, 2-3 times per week, once a week, less than once a week and never.

Table 5. Activity frequency reporting (%)

	Daily	2-3 days/week	1/week	< 1/week	Never
School computer use	8.8	10.7	12.8	50.2	17.4
Home computer use	54.2	22.9	8.8	9.2	4.8
TV-based game use	31.7	23.7	12.4	17.9	14.3
Hand-held game use	9.0	11.3	9.7	25.4	44.1
Television watching	62.2	24.6	7.4	4.8	0.8
Exercise	39.7	35.5	12.6	6.3	5.7

Daily school computer use was reported by only 9% of respondents, but one third respondents used a computer at school at least once a week – this would correspond to taking a computer class that met once a week or using the computer occasionally in other classes or for library work. About half (54%) of this sample reported daily home computer use. This is close to the national rate of 51% in children aged 8-18 reported by the Kaiser Family Foundation (1999). Daily television watching was reported by 62% of the subjects. About a third used TV based games daily, and

40% exercised daily. Almost half (44%) never used handheld games, 79.5% used them weekly or less and only 9% used them daily. The results are similar to data available from Gallup and U.S. Census surveys (Mason, 2004, U.S. Census Bureau, 2001). What proportion of homes possessed a computer, television or electronic games was not assessed.

Responses for all activity variables ranged from 1 to 5. The activity frequencies are all fairly skewed. Rather than being equally distributed across all frequency categories, daily activity was more common for all activities except for hand-held game use and school computer use. Most respondents do these two activities infrequently.

Table 6. Percentage of participants engaging in activities daily, by gender, race and age

	Gender		Race		Age		
	Boys	Girls	White	Nonwhite	<=14	>14-16	>16-19
N	212	224	367	90	298	91	87
Home computer	52	59	57*	44*	54	53	55
School computer	10	8	9	8	8	10	10
TV-based game	50*	12*	30	40	35*	34*	17*
Hand-held game	12*	4*	8	14	10*	11*	3*
TV watching	65	60	61	67	68*	58*	47*
Exercise	46*	34*	42*	32*	42	37	33

*Pearson X^2 significant at $p < 0.05$

Activity frequency was not consistent across demographic groups. Table 6 shows the distributions of daily activity by gender, race and age level. Girls were notably less likely to play TV-based or hand-held games or to exercise daily. Electronic game use and TV watching decreased with age; exercise decreased marginally. Non-white or multiracial subjects were less likely to use home computers or TV-based games daily.

Activity time

More people used computers for long periods than use TV-based and handheld games. Predictably, mean use was longer for all activities on the weekend than on weekdays. Television occupied the most time, followed by home computer use. School computer use contributed little to the overall electronic activity.

Table 7 shows the median and mode of the longest time spent without a break at each activity on a typical day.

Table 7. Longest time spent without a break

	Median	Mode
School computer	0.5-1 hr	<0.5
Home computer	1.0-1.5 hr	>=2 hrs
Handheld game	<0.5 hr	None
TV-based game	0.5-1 hr	>=2 hrs

Distribution of activity time compared to frequency of use

Daily home computer users also used the computers for longer times. The mean daily use was significantly higher in daily users compared to all other users (2.2 compared 0.9 hours on weekdays, 2.9 compared to 1.3 on a weekend day, $p<.001$). This was not just because subjects who never use computers were included, as shown in table 8. Mean use also differed between daily home computer users and moderate users ($p<.001$).

Table 8. Mean hours of home computer use on a typical day

	Hours per week day*		Hours per weekend day*	
	Daily users Mean (SD)	Less frequent Mean (SD)	Daily Mean (SD)	Less frequent Mean (SD)
All respondents	2.2 (1.3)	0.9 (1.0)	2.9 (1.5)	1.3 (1.30)
Using computer > once/week	2.2 (1.3)	1.3 (1.1)	2.9 (1.5)	1.7 (1.4)

* means differ significantly between daily and less frequent users at $p<.05$

Years of activity

The average respondent had been using a computer at school for about five years and had been using home computer and handheld and TV based games for a little longer. Respondents started using computers at school and at home at about nine years of age and the other technologies around eight. Table 9 shows the range and standard deviations.

Table 9. Initial use of technology

	Years since first use Mean (SD)	Age at first use Mean (SD)
Home computer	5.6 (2.5)	8.6 (2.5)
School computer	5.0 (2.3)	9.2 (2.0)
Handheld game	6.1 (2.9)	8.1 (2.5)
TV-based game	6.5 (2.8)	7.7 (2.5)

5.2.2. Postural and use type measures

As shown in table 10, the majority of subjects (56.5%) reported using a computer as their most common device, with 3.8% on a laptop and 52.7% on a desktop. TV-based games were the second most commonly used at 37%.

Table 10. Device used most frequently

Device	%
Desktop computer	52.7
Notebook computer	3.8
TV-based game	36.6
Hand-held game	3.6
Other	0.8
Multiple	2.3

Home use of the primary device was reported by 93% of respondents, as shown in table 11.

Table 11. Most frequent location for device use

	%
Home	93.3
School	2.7
Carry	1.3
Other	2.3

A preponderance of respondents used a mouse as an input device (60% of the total sample, 92% of all those who use computers as their main device), followed by 34% reporting primarily game controller use, as shown in table 12. Using more than one type of input device was reported by 18%.

Table 12. Control device use (%)

	Primary	Secondary
Mouse	59.7	0.6
Touchpad	1.9	9.7
Track ball	1.5	1.3
Joy stick	3.8	1.7
Game controller	30.3	4.0
Eraser head	0.6	0.2
Other	0.8	0.6

Almost all (95%) of the respondents found the equipment they used comfortable; only 3% found it uncomfortable. Predictably, the postures adopted differ between subjects who use computer most and those who use games most. The positions for game use are more widely distributed than for computer use. Sitting or lying on the floor, couch or bed was common for game users, as expected. But even the computer users are not all sitting at a desk: About 13% of computer users work sitting on the floor at least half the time, and 23% use the computer while they lie on a bed or couch at least half the time.

As explained in the Methods chapter, the demands of the equipment placement were ranked from high to low, based on the expected deviation from neutral posture and potential biomechanical demand. Postural demand from monitor, keyboard and input device placement was mixed, as shown in table 13. Only 32% of respondents use their computers with the monitor directly on the table (the best position for maintain the correct neck angle for most people). More (42%) kept the monitor on a shelf, which is almost certainly too high even for adults. Half the respondents had the keyboard on a tray lower than the desk, which should improve elbow and shoulder angles if the keyboard tray is low enough. However, a quarter were probably raising the shoulders and arms to reach a keyboard on the table surface. Almost one-third used the mouse on a tray lower than the table, but 46% used it on the table, suggesting that they are increasing their risk of shoulder, neck, arm and hand problems by reaching forward and perhaps to the side to use the mouse (causing excessive shoulder flexion and arm abduction). Two-thirds report that their feet easily touch the ground.

Table 13. Subjects reporting each device position (%)

	Highest demand	Medium demand	Least demand	Neutral, unknown or blank
Monitor	41.6	14.7	34.9	8.8
Keyboard	23.7	5.5	49.6	21.2
Input/mouse	45.8	11.6	31.9	10.7
Feet	3.2	20.6	66.8	9.5

5.2.3. Outcomes measures

Symptoms prevalence and frequency

Subjects were asked to report symptoms in three ways: by making a mark on a body map to indicate symptoms occurring in the past month, by recording symptoms frequency and by recording symptoms intensity. As explained earlier, the main outcome of interest is the reporting of neck or upper extremity symptoms on the body map.

Table 14 shows the distributions of symptoms prevalence in each area in the past month. More than two-thirds (71%) marked some symptoms. Almost one-half marked some area of the neck or upper extremities, which was defined earlier as the outcome of interest in this study. Lower extremity symptoms were reported by 30.5% of all subjects. Neck symptoms and lower back symptoms were equally common at about 28%. Wrist or hand, midback and upper back symptoms were each reported by fewer than 20%

In a similar study, reported 6 months cumulative incidence of neck and upper extremity symptoms occurring at least weekly were lower than those seen here, but the relative ordering of symptoms frequencies was the same, with the most symptoms in the neck and the least in the arms or hands (Feldman, et al., 2002). The rate of low back symptoms was similar to child community prevalence estimates (Malleson and Clinch, 2003).

Table 14. Subjects marking symptoms on the map, ranked by reporting frequency

Area	N	%
Any	337	70.8
Any neck or upper extremity	219	46.0
Hips, legs or feet	145	30.5
Neck	137	28.8
Lower back	132	27.7
Wrists or hands	95	20.0
Midback	94	19.7
Upper back	77	16.2
Shoulder	62	13.0
Arms or elbows	52	10.9

Like activity, symptoms reporting was affected by gender and age, as shown in table 15.

Table 15. Symptoms occurrence in the past month by demographic categories (% reporting)

	Gender		Age			Race	
Symptoms site (N)	Boys (212)	Girls (224)	<=14 (298)	>14-16 (91)	>16-19 (87)	White (367)	Nonwhite (109)
Neck (137)	21*	36*	29	30	29	29	28
Upper back (77)	12*	20*	16	12	20	16	16
Shoulder (62)	11	15	14	7	16	14	10
Arms/elbows (52)	11	8	12	7	11	11	10
Wrists/hands (95)	20	20	22	15	18	19	23
Midback (94)	17	22	20	18	21	19	21
Low back (132)	24	30	22*	31*	44*	27	29
Hips/legs/feet (145)	31	28	33	29	25	30	32

*Pearson’s chi-square significant at p<.05

Girls were more likely than boys to report neck or upper back symptoms, and older children were more likely than younger to report lower back symptoms. This study did not show any difference in symptoms reporting by race.

The distribution of reported symptoms frequency on five point scales (daily to never) is shown in table 16.

Table 16. Symptoms frequency by location (%)

Symptoms site	Daily	2-3 days/wk	1/wk	<1/wk	Never
Neck, upper back	6.1	5.5	8.6	34.0	42.0
Shoulder, arms, elbows	4.4	2.9	5.0	24.3	61.7
Wrist, hands	4.8	1.5	4.4	25.0	61.8
Lower back	6.9	5.9	9.2	22.5	52.1
Hips, legs, feet	5.0	4.6	8.0	18.3	63.0

The categories for the symptoms frequency scale were, inadvertently, slightly different than those for the body map: neck and upper back were reported together, as were shoulders, arms and elbows. More subjects marked symptoms on the intensity and frequency scales than reported symptoms in the past month on the body map, for all body areas. This suggests that the scales encourage the reporting of less memorable or significant symptoms. However, comparing these measures was difficult as the reporting categories were not identical.

Daily symptoms were most common in the low back, followed by the neck and upper back. Overall, more respondents reported some symptoms in the neck and upper back (58%) than in the low back (48%) or any other area (less than 40% each).

Symptoms intensity

Table 17 shows the pattern of reporting by symptoms intensity as marked on the five-point scale ("as bad as possible" to "none"). A greater proportion of neck and upper back symptoms were reported as being of medium or greater intensity (33%) than reported for the other areas.

Table 17. Symptoms intensity (% reporting)

Symptoms site	As bad as possible	Bad	Medium	Slight	None
Neck, upper back	1.9	9.5	21.4	25.6	41.6
Shoulder, arms, elbows	1.3	4.4	13.2	19.1	62.0
Wrist, hands	1.7	5.5	8.8	23.3	60.7
Lower back	2.5	11.1	4.9	19.1	52.3
Hips, legs feet	2.1	5.2	14.5	16.0	62.2

Symptoms severity

Severity was calculated as the number of days per month (converted from the original scale to produce possible values of 0, 2, 4, 12, or 28) multiplied by the intensity rating (5=As bad as possible, 4=Bad, 3=Medium, 2=Slight and 1=None). Scores ranged from 0 to 112 for all variables. Symptoms severity statistics are laid out in table 18.

Table 18. Symptoms severity scores

	Mean (SD)
Lower back	9.5 (23.4)
Neck, upper back	8.2 (19.5)
Hips, legs, feet	6.3 (19.1)
Shoulder, arms, elbows	5.2 (16.8)
Wrist, hands	2.0 (9.0)
Neck, upper extremities	11.1 (23.3)

The interpretation of the severity score is not straightforward: A score of 10 could result from a symptoms judged “as bad as possible” that happened once or twice, whereas 12 could mean that medium intensity symptoms occurred weekly. The mean scores are strongly affected by the many subjects who reported no symptoms or low intensity.

The combined neck and upper extremities area had the highest mean symptoms severity score, not surprisingly as this variable combined three areas. The highest mean in one area was in the lower back, followed by the neck or upper back and the shoulders, arms or elbows.

All of the severity distributions are highly skewed and kurtotic, so estimates from analyses highly dependent on normality may not be precise or stable.

Reported causes

Some respondents felt they knew why they experienced symptoms. The distributions of these responses are shown in table 19. Computers and games were blamed for half the symptoms in the wrist and hand, and 18% of symptoms in the neck and upper back. Other ergonomics issues, such as chairs and typing, were thought responsible for almost one quarter of the neck and upper back and the lower back symptoms, and 16% of symptoms in the wrist and hand. Sport was blamed for more than half of the arm and elbow and lower extremity problems, one third of the wrist and hand problems and 16% of the neck and upper back symptoms. Specified illnesses or accidents were thought to contribute no more than 16% to any symptoms.

Table 19. What subjects report causes symptoms (as % of subjects with each symptom)

	Neck, upper back	Shoulders, arms, elbows	Wrists, hands	Lower back	Hips, legs, feet	Total
Computer/game	17.7	8.5	52.1	7.6	0.7	99
Other ergonomics issue	22.3	8.5	16.0	23.5	2.8	97
Sports, dance or exercise	16.0	55.3	35.1	34.1	60.0	245
Musical instrument	0.0	2.1	3.2	0.0	0.0	5
Postural problems	7.4	0.0	0.0	11.4	0.7	29
Health/accident	4.6	12.8	16.0	14.4	15.9	77
Backpack	2.9	4.3	1.1	3.8	0.0	15
Behavior	12.6	10.6	4.3	12.9	5.5	61

As with the symptoms severity and intensity scales, through an oversight the body part categories in the survey did not exactly match the areas coded on the body map.

Effect of symptoms on behavior

Subjects were asked to report what they had done in response to the pain or discomfort they had reported, as shown in table 20. More than 40% of the subjects with symptoms did something. Those with neck or upper extremity symptoms were significantly more likely to do something, compared to subjects with other symptoms. The most common action was taking medication, followed by seeing a doctor. Those reporting neck or upper extremity symptoms were significantly more likely to reduce computer and game use than those with symptoms in other areas. Their rates for taking medicine, missing school, and making other changes were slightly higher among those with neck or upper extremity symptoms, but the differences were not significant

Table 20. % reporting change in behavior related to reported pain or discomfort

	Among those with NUE symptoms (N=219)	Among those with other symptoms (N=118)	Entire group (N=476)
Any change	44.3	40.1	36.4
Took medicine	27.9	21.0	20.1
Saw doctor	11.0	12.8	9.7
Made other changes	10.5	7.7	8.4
Exercise reduced/eliminated	9.1	10.3	7.6
Computer reduced/ eliminated	9.1*	1.7*	5.9
Missed school	8.2	6.8	6.3
Games reduced/eliminated	5.9*	1.7*	3.8

*independent samples test of proportions significant at p<.05

5.3. Associations

5.3.1. Correlations among activity items

Correlations among the reported 5-level activity frequency variables are illustrated in table 21.

Table 21. Correlations between activity frequency variables

	School computer	Home computer	TV-based game
Home computer	-.07		
TV-based game	.07	-.03	
Hand-held game	.08	-.12*	.37*

*Spearman's rho is significant at p<.05

Frequency of handheld game use and TV-based game use are correlated (Spearman's coefficient=0.37): more frequent hand-held game users are also more frequent TV-based game users. School and home computer use frequency were not correlated. Home computer use frequency was not significantly associated with TV-based game use frequency. Although school computer use and hand-held game use were mildly correlated, when the analyses were split by age or gender the correlation disappears (data not shown). An important implication of these results is that frequency of electronic activity was not consistent across all devices – heavier home computer users were not heavier school computer users or game users.

Weekend and weekday times are strongly correlated within each activity – if you do an activity longer during the week you are likely to do it longer on the weekend (data not shown). There was a small but significant relationship between TV-based and hand-held game use times.

In contrast with activity frequencies, those who use one technology for longer without a break do so with the others. The correlations among reported longest activity without a break are shown in table 22. Most activities are very slightly correlated, and the significant correlations remain when analyzed separately by gender and age level.

Table 22. Correlations among typical longest use without a break

	School computer	Home computer	TV-based game
Home computer	.13*		
TV-based game	.10*	.09	
Hand-held game	.13*	.07	.37*

*Spearman's rho is significant at p<.05

Kids who use equipment longer without a break are also more frequent users, as shown in table 23. Longest use and frequency of use are moderately to highly correlated for each activity. Frequency and duration are moderately correlated between types of game use. Finally, hand-held game use frequency was correlated with longest school based computer use, but this association was seen in girls only.

Table 23. Correlations between activity frequency and longest use without a break

	Longest use without a break			
Activity frequency	School computer	Home computer	TV-based game	Hand-held game
School computer	0.46*	0.09	0.05	0.05
Home computer	-0.04	0.46*	-0.08	-0.07
TV-based game	0.06	0.08	0.75*	0.34*
Hand-held game	0.11*	0.04	0.34*	0.88*

* Spearman's rho is significant at p<.05

5.3.2. Associations among symptoms prevalence areas

Respondents who mark symptoms on the body map in one area are likely to report them in others. Most areas are associated with symptoms in every other area, except arms and elbows symptoms are not associated with back symptoms.

The body map was not marked by 30% of respondents. There will be a strong correlation among all symptoms locations because so many responses are negative. Among those reporting any symptoms (N=337), symptoms are associated in 50% of the pairs (partial tau b significant at p<.05, adjusted for age, race and gender, data not reported). None of the associations were strong, (tau b=0.12-0.35); the strongest associations were among the back areas.

5.4. Modeling

The associations between activities and symptoms occurrence in the past month were modeled using unconditional logistic regression. All variables were entered together. The primary outcome of interest was the dichotomous variable reflecting the occurrence of any combination of neck or upper extremities symptoms in the past month, as these are the areas most affected by computer use in adults. A case in this model was any subject marking the neck, shoulder, arms or hands as occurring in the past month on the body map. Associations with symptoms intensity and frequency were also tested.

In later sections, the possible mediating effect of exercise, school level and body mass index are assessed. Post hoc analyses of the relationships between all activities, all symptoms areas and some personal characteristics will be described. Except where noted, all logistic regression analyses are adjusted for age as a continuous variable, gender and race.

5.4.1. Testing hypothesis 1: Activity frequency and symptoms occurrence

Neck or upper extremity musculoskeletal symptoms are associated with home computer use frequency.

The odds of reporting neck or upper extremity symptoms in the past month increased significantly among those who used a computer daily at home compared to those who used it less (unadjusted OR=1.7, 95% CI=1.2-2.4), as shown in Table 24.

Table 24. Odds ratios (ORs) for reporting neck or upper extremity (NUE) symptoms in the past month for daily compared to less frequent home computer use

NUE symptoms, N (%)		OR (95% CI)	
Daily users	Less frequent users	Unadjusted	Adjusted
134 (51.9)	85 (39.0)	1.7 (1.2-2.4)	1.7 (1.1-2.5)

The effect of daily home computer use compared to weekly or less was the same (OR=1.6, 95% CI=1.0-2.5, p=0.04), as shown in table 25.

Table 25. Odds ratios (ORs) for reporting neck or upper extremity (NUE) symptoms for daily or moderate home computer use compared to infrequent use

		OR (95% CI)	
Frequency	NUE Symptoms N (%)	Unadjusted	Adjusted
Daily	134 (51.9)	1.6 (1.0-2.5)	1.5 (0.93-2.5)
2-3/wk	41 (37.6)	0.89 (0.52-1.5)	0.82 (0.45-1.5)
Weekly or less	44 (40.4)	1	1
p_{trend}		0.02	0.03

The test for linear trend across the three use frequencies (weekly or less, 2-3 times a week and daily or almost daily) was significant (p=0.02). However, using the computer 2-3 times per week compared to weekly or less did not significantly affect the odds of reporting symptoms in the neck or upper extremities (OR=0.89, 95% CI=0.52-1.5). Thus daily use rather than 2-3 times a week or less seems responsible for the increased odds of reporting neck or upper extremity symptoms.

In both analyses, the results are the same when the relationship is adjusted for gender, age and race. This indicates that these demographic characteristics are not significant confounders in the relationship between home computer use frequency and symptoms reporting. However, because of their demonstrated correlations with symptoms and activities reported here and in other literature, they were adjusted for throughout.

Neck or upper extremity symptoms are not associated with school computer use, hand-held game use or TV-based game use

Notably, only daily home computer use increased the odds of reporting symptoms in the neck or upper extremities. The odds were not affected by daily school computer use, hand-held game use or TV-based game use. The odds ratios produced from the logistic regression using these variables are shown in table 26.

Table 26. Odds ratios for reporting neck or upper extremity symptoms by daily compared to less frequent electronic device use

	NUE symptoms N (%)		OR (95% CI)	
	Daily users	Less frequent	Unadjusted	Adjusted*
School computer	20 (47.6)	199 (45.9)	1.1 (0.57-2.0)	1.0 (0.53-2.0)
TV-based game	65 (43)	154 (47.4)	0.84 (0.57-1.3)	0.91 (0.58-1.5)
Hand-held game	16 (37.2)	201 (46.6)	0.68 (0.36-1.3)	0.68 (0.32-1.4)

* Adjusted for gender, age and race

Home computer use frequency was related to intensity and frequency of symptoms

Symptoms intensity was also predicted by home computer use frequency. This is shown in table 27. Daily home computer use was associated with reporting symptoms as medium or worse on an intensity scale. The odds of reporting symptoms weekly or more often were increased in daily home computer users compared to less frequent users (marginally significant at p=0.05).

Table 27. Odds ratios for reporting neck or upper extremity (NUE) symptoms of medium intensity or at least weekly related to daily home computer use

Symptoms category	NUE symptoms N (%) Daily users	Less frequent users	OR (95% CI)
Intensity >= medium	130 (50.4)	84 (38.5)	1.7 (1.2-2.5)
Symptoms >= weekly	81 (31.4)	54 (24.8)	1.5 (0.99-2.4)

Home computer use frequency was not associated with an increase in symptoms outside the neck or upper extremities

The association between daily home computer use and symptoms across the body map was evaluated; results are shown in table 28. Daily use was associated with increased symptoms in the neck and in the shoulders symptoms, however significance was marginal (OR=1.5, p=0.09 and OR=1.8, p=0.06, respectively). Home computer use frequency did not predict symptoms in any other area.

Table 28. Odds ratios for reporting symptoms related to daily home computer use

	Symptoms n (%)		
	Daily use	Less frequent	OR (95% CI)
Neck	84 (32.6)	53 (24.3)	1.5 (0.95-2.2)
Shoulders	41 (15.9)	21 (9.6)	1.8 (0.98-3.3)
Arms or Elbows	30 (11.6)	22 (10.1)	1.1 (0.58-2.1)
Wrists or hands	55 (21.3)	40 (18.3)	1.2 (0.72-1.9)
Upper back	46 (17.8)	31 (14.2)	1.1 (0.67-1.9)
Mid back	54 (20.9)	20 (18.3)	1.2 (0.74-1.9)
Lower back	77 (29.8)	55 (25.2)	1.2 (0.75-1.8)
Hips, legs or feet	79 (30.6)	66 (30.3)	1.1 (0.71-1.6)

Home computer use frequency was associated with neck or upper extremity symptoms severity

Linear regression of neck or upper extremity symptoms severity (days per month*intensity) on computer use frequency produced results consistent with the logistic regression of computer use on symptoms reported on the body map in the past month. The regression equations included activity frequency, gender, age in years, and race, and only the gender and computer use terms were significant ($p=0.03$). The mean severity score was significantly higher for daily home computer users (13.5 compared to 8.3). No other activity predicted symptoms severity in this area.

Changing computer use because of symptoms does not affect the observed odds ratios

A logistic regression was also run to clarify whether subjects who thought they were affected by the computer had limited or otherwise changed their computer use habits. This could have led to a misclassification of exposure among those who knew or believed they had developed computer-related symptoms. The odds ratios were dramatically larger among those who report reducing or eliminating computer use because of symptoms. However, these odds ratios are non-significant and clearly unstable, due to the small number of people who changed their computer behavior because of symptoms (N=28). This is illustrated in table 29.

Table 29. Odds of reporting neck or upper extremity symptoms related to daily home computer use by activity change category, adjusted for sex, race and age

Change category (N)	NUE symptoms N (%)		OR (95% CI)
	Daily use	Less frequent	
Reduced/eliminated computer (28)	15 (83.3)	5 (50.0)	5.4 (0.62-47)
Did not reduce/eliminate (449)	119 (49.8)	80 (38.5)	1.6 (1.1-2.4)
Changed any behavior (173)	62 (62.6)	35 (47.3)	1.7 (0.88-3.3)
Changed no behavior (303)	72 (45.6)	50 (34.7)	1.6 (0.98-2.6)

Neck or upper extremity symptoms were attributed to a health problem or accident by 27 subjects; the odds of reporting these symptoms related to daily home computer use were the same when these subjects were removed from the analysis (OR=1.6, 95% CI=1.1-2.3, p=0.02).

5.4.2. Testing hypothesis 2: Activity time and symptoms occurrence

Longer average home computer use was not associated with neck or upper extremity symptoms

Logistic regression was used to explore whether typical daily home computer use time, without regard to frequency, may also be associated with higher odds of reporting neck or upper extremity symptoms. As described in section 5.2.1, daily users spent more time on the computer than less frequent users, on weekdays and on weekends. However, in this study increasing daily time of computer use was not a predictor of symptoms reporting. Daily average time estimates entered into the logistic regression (as a five-level categorical variable, a three level categorical variable or converted to a continuous variable of hours based on the midpoint of the reported 5-

level time range) were not significantly associated with neck or upper extremity symptoms (data not reported).

Longest computer use at a time shows some relationship to neck or upper extremity symptoms

The duration of use without a break may be a more significant risk for musculoskeletal disorders than time spent, because sustained and static demands are implicated strongly in disorders of the neck or upper extremities (Bernard, 1997, National Research Council and Institute of Medicine, 2001, Punnett, 1994). Those who report normally using a computer at home for more than two hours without a break are marginally more likely to report symptoms (adjusted OR = 1.8, p=0.08) than those who use computer for less than half an hour, as shown in table 30.

Table 30. Odd ratios for neck or upper extremities symptoms reporting and uninterrupted duration of use, adjusted for race, gender and age

Use duration	NUE Symptoms N (%)	OR (95% CI)
>=2 hrs	81 (46.6)	1.8 (0.92-3.6)
.5-1.5hrs	116 (48.9)	2.1 (1.1-4.0)
<.5	21 (33.9)	1.0
p_{trend}		0.1

Those whose longest use is 0.5-1.5 hours are also significantly more likely to report symptoms than those using computers less (OR=2.1, p=.03). The trend across use levels is not significant at the p<.05 level.

Duration of use of electronic games and duration of computer use at school are not significant predictors of symptoms in the neck or upper extremities (data not reported).

The relationship between years of use and neck or upper extremity symptoms

Odds ratios from the logistic regression of years of activity (a continuous variable) on neck or upper extremity symptoms reporting are shown in table 31. There was no apparent association between the number of years since first computer use and neck or upper extremity symptoms. The same was true when the exposures were entered as categorical variables based on tertiles (data not reported). However, longer TV-based game use in years was significantly associated with neck or upper extremity symptoms. Each year of use was associated with a 10% increase in the odds of reporting symptoms.

Table 31. Odds ratios for neck or upper extremity symptoms by years of use, adjusted for age, gender and race

	OR[a]	95% CI	p
Computer at home	1.0	0.95-1.1	.4
Computer at school	0.94	0.84-1.0	.2
Hand-held game	1.0	0.92-1.1	.8
TV-based game	1.1	1.0-1.2	.04

[a]Odds ratio for each year of use

5.4.3. Testing hypothesis 3: Posture and symptoms occurrence

In this study, posture-related demand was inferred from the ergonomic setup of the workstation. Each piece of equipment was coded as a categorical variable. The relationship between each variable and neck or upper extremity symptoms was assessed in a logistic regression, adjusted for race, gender and age. No position of monitor, keyboard, mouse, lighting or foot support showed a significant relationship with symptoms at the $p<0.05$ level.

Whether subjects used computers or game devices most did not affect symptoms reporting in the neck or upper extremities. In particular, predominantly computer users do not report more symptoms than predominantly game users (OR=1.25, p=0.4), although computer use might be thought to pose a more consistent risk, based on the data reported so far.

To explore whether the equipment position had different effect within the use types, computer users and game users were analyzed separately; results are shown in table 32. For computer users only foot positions verge on significance for predicting neck or upper extremity symptoms, however the confidence intervals are quite large. (OR=5.4, p=0.1 for “feet do not reach ground;” OR=1.9, p=0.06 for “foot position varies;” and OR=2.2, p=0.1 for “other,” all compared to “feet easily touch ground.”)

Table 32. Odds of reporting neck or upper extremity symptoms by equipment position, analyzed by predominant device use category

Computer users (N=238)	Monitor OR (95% CI)	Keyboard OR (95% CI)	Mouse OR (95% CI)	Feet OR (95% CI)
Highest demand	1.0 (0.56-1.7)	0.80 (0.24-2.7)	0.71 (0.11-4.6)	5.4 (0.61-48)
Moderate demand	0.77 (0.37-1.7)	1 (0.58-1.7)	1.1 (0.66-1.9)	1.9 (0.97-3.7)
Neutral or unknown	0.86 (0.16-4.5)	Not applicable	No responses	2.2 (0.83-6.0)
Lowest demand	1	1	1	1

Game users (N=152)	Monitor OR (95% CI)	Keyboard OR (95% CI)	Control device OR (95% CI)	Feet OR (95% CI)
Highest demand	1.6 (0.72-3.4)	1.2 (0.28-4.9)	0.62 (0.27-1.4)	0.74 (0.34-1.6)
Moderate demand	1.5 (0.53-4.0)	1.9 (0.77-4.7)	0.29 (0.11-0.7)	1.1 (0.24-5.4)
Neutral or unknown	2.9 (0.43-19)	0.72 (0.33-1.6)	0.47 (0.08-2.9)	1.5 (0.53-4.4)
Lowest demand	1	1	1	1

Among game users the demanding monitor positions were associated with non-significant but increased odds ratios (OR=1.5 for monitor on the computer top; 1.6 for monitor on a shelf; OR=2.9 for monitor attached to computer or there is no monitor), compared to ratios around 0.9 for the computer users. Among game users, using the control device on the lap was significantly protective (OR=0.29, p=.01)

5.4.4. Exploring research questions: Other associations between activities or personal characteristics and musculoskeletal symptoms

The effect of gender on computer-related symptoms reporting

The relationship between home computer use frequency and symptoms was explored further to identify the effect of gender in the logistic regression equation. Gender was a significant independent predictor of neck or upper extremity symptoms reporting. It remains significant when entered into the logistic regression with home computer use frequency (OR for girl vs. boy=1.6, 95%CI= 1.1-2.3, p=0.02). The impact of daily home computer use does not change when adjusting for gender, race and age, as shown in table 26 above. An interaction term for gender and home computer use frequency does not enter significantly into the model.

Table 33. The impact of gender on the odds of reporting symptoms related to daily home computer use, adjusted for age and race

	NUE symptoms N (%)		
Group	Daily use	Less frequent	OR (95 % CI
Girls (224)	75 (56.8)	40 (40.3)	1.7 (0.99-2.9)
Boys (212)	50 (45.0)	33 (32.7)	1.7 (0.95-2.9)
Gender unknown (40)	9 (60)	12 (48.0)	1.8 (0.47-7.0)

As shown in table 33, the effect of daily home computer use was the same in girls and boys analyzed separately (OR= 1.7, marginally significant at p=0.07 for boys and p=0.06 for girls), and in the small group that did not report gender (OR=1.8, non-significant for these 40 cases). Thus gender did not confound the relationship between symptoms reporting and home computer use frequency, although it was an independent predictor of these symptoms.

The impact of exercise on computer-related symptoms reporting

Exercise was not an independent predictor of reporting neck or upper extremity symptoms. Exercise did not predict symptoms reporting when entered into a logistic regression alone, when adjusted for gender, or when entered into the model along with home computer use frequency, age, gender and race.

Exercise did appear to slightly attenuate the relationship between daily computer use and neck or upper extremity symptoms reporting, as shown in table 34.

Table 34. Odds ratios for reporting neck or upper extremity symptoms by daily home computer use and exercise level

	NUE symptoms N (%)		
Group (n)	Daily home computer	Less frequent	OR ((95% CI)
Do not exercise daily (286)	86 (57.0)	53 (39.0)	1.9 (1.1-3.1)
Exercise daily (189)	48 (44.9)	32 (39.0)	1.4 (0.74-2.7)

Among those who did not exercise daily the odds for reporting neck or upper extremity symptoms increased with daily computer use compared to less frequent use (OR=1.9, 95% CI = 1.1-3.1). Daily home computer users who did exercise daily were not significantly more likely to report neck or upper extremity symptoms than those who used computers less (adjusted OR=1.4, 95% CI=0.74-2.7).

From these results it seems that exercise might provide some protection from the negative effects of daily computer use. However, there was no significant interaction effect of exercise by computer use or exercise by gender that would support a simple moderation effect of exercise.

Age, grade and school level

The association between home computer use frequency and neck or upper extremity symptoms was strongest in the oldest subjects. Table 35 shows the odds ratios for each 2-year age group. Despite the smaller sample size, the odds of reporting these symptoms triples in the older high schoolers who use the computer daily compared to those using a few times a week or less. In the middle age group the odds related to daily use was twice that for the comparison categories, but the effect was not significant (p=0.1). In the youngest group, there was no increase in odds with daily computer use.

Table 35. Odds ratios for reporting neck or upper extremity symptoms related to daily home computer use by age level, adjusted for gender and race

	NUE symptoms N (%)		
Age level	Daily use	Less frequent	OR (95.0%)
>=16	28 (58.3)	13 (33.3)	3.3 (1.3-8.6)
>14-<16	23 (47.9)	14 (32.6)	2.1 (0.84-5.3)
<=14	85 (51.2)	58 (42.6)	1.3 (0.82-2.3)

These findings are supported by the observation of a moderate but not significant age level and computer use frequency interaction effect on neck or upper extremity symptoms reporting when age level was entered as an interval variable in the logistic regression equation (OR for age level*daily use = 1.5, p=.12). However , age level itself does not significantly predict symptoms, and the difference in symptoms is not significant between age levels (Pearson chi-square =1.3, p=.5).

The high school subjects, grades 9-12, are predominantly responsible for the observed increase in odds of symptoms with daily home computer use – there was no significant effect of computer use in the younger group. School level itself was not a predictor of symptoms entered into a regression equation with race and sex (OR=.99, p=.99). The interaction term (school level*daily home computer use) was large and close to significance when age was also included in the equation (OR=2.2, 95% CI= 0.96-5.1). The term was not significant (OR=1.1, 95% CI=0.83-1.4) if age was not adjusted for. All other results of stratifying by school level and age level are consistent with earlier findings: no activity other than home computer use predicts upper extremity and neck symptoms.

Within the middle school students, the effect of daily home computer use was not consistent. Table 36 shows the odds ratios for each school. The two high schools show similarly increased odds ratios. Daily home computer users in middle school 2 also have increased odds of reporting neck or upper extremity symptoms, while daily users in the other two middle schools do not.

Table 36. Odds ratios for reporting neck or upper extremity symptoms by daily home computer use, stratified by school, adjusted for gender and race

SCHOOL (Grade)	NUE symptoms N (%) Daily use	Less frequent	OR (95% CI)
HS1 (11-12)	21 (55.3)	8 (28.6)	3.2 (1.1-9.9)
HS2 (9-10)	29 (54.7)	15 (34.1)	2.8 (1.1-6.8)
MS1 (7-8)	27 (47.4)	18 (43.9)	1.3 (0.55-3.1)
MS2 (7-8)	21 (40.4)	11 (22.4)	2.5 (0.96-6.2)
MS3 (7-8)	36 (62.1)	33 (58.9)	0.87 (0.39-2.0)

Associations between other activities and reporting symptoms

Table 37 lists the only other associations between activities measured and symptoms.

Table 37. All significant odds ratios for symptoms and daily activity, adjusted for age, race and gender

Activity and symptom area	NUE symptoms N (%) Daily activity	Less frequent	OR (95% CI)
Reading and shoulder	23 (20.4)	39 (10.7)	2.0 (1.1-3.7)
TV-based game use and midback	33 (21.9)	61 (18.8)	1.8 (1.0-3.2)
TV watching and midback	67 (22.6)	26 (14.5)	1.7 (1.0-3.0)
Exercise and hips/legs/feet	72 (38.1)	73 (25.4)	1.7 (1.1-2.6)

TV watching, TV-based game use, exercise and reading were each associated with some symptoms, School computer use and hand-held game use were not. Reporting midback symptoms was significantly associated with both daily television viewing (OR=1.7, p=0.04) and daily TV-based game use (OR=1.8, p=0.04), compared to less frequent use. Daily exercise was associated with an increase in hip, leg and foot symptoms (OR=1.7, p=0.01), and daily reading was associated with increased shoulder symptoms (OR=2.0, p=0.01).

It could be argued that a Bonferroni correction for confidence level should be used when evaluating the many relationships between activity frequency and symptoms reporting. Unlike the associations between computer and game use and upper extremity symptoms, these are post hoc analyses not stated in the study hypotheses. Using the Bonferroni adjustment, the p value should be .001 (.05 divided by 45, for 5 activities and 9 areas of the body). When corrected for these multiple comparisons only the relationship between daily physical activity and lower extremity symptoms retains significance.

Association between symptoms variables and other personal factors

a. Overweight status

The role of weight was not included in the original hypotheses. However, weight and height data were collected and analyzed, within the reporting and reliability limitations described in the Methods chapter. When adjusted for race, gender and age, there are no significant correlations between overweight status and any activity frequency level, including computer use.

The impact of BMI on symptoms was assessed as a dichotomous variable (not at risk vs. at risk or overweight) in a logistic regression adjusted for age, gender and race. Being overweight or at risk of overweight was significantly associated with neck or upper extremity symptoms (OR=1.9, 95% CI=1.1-3.2, p=0.03). Including overweight status in the equation did not affect the odds of reporting neck or upper extremity symptoms for daily compared to less frequent home computer users.

b. Vision correction

Those who reported wearing glasses or contact lenses were more likely to report symptoms in the upper back, midback and shoulder, as shown in table 38.

Table 38. Symptoms associated with using glasses or contact lenses, compared to uncorrected vision, adjusted for gender, age and race

	Symptoms N (%)		
Area	Correction	No correction	OR (95% CI)
Upper back	33 (21.2)	40 (13.6)	1.8 (1.0-3.1)
Shoulder	29 (18.6)	32 (10.9)	2.0 (1.1-3.5)
Midback	40 (25.6)	29 (16.7)	1.7 (1.1-2.9)
Neck or upper extremities	84 (53.8)	122 (41.5)	1.5 (0.96-2.2)

This association was not changed when adjusted for reading frequency, as might be expected given the reported association between reading and myopia (Angle and Wissmann, 1978, Parssinen and Lyyra, 1993) and between shoulder symptoms and reading reported here.

Vision correction was marginally associated with increased reporting of symptoms in the neck or upper extremities, but not with daily home computer use. Including vision correction in the logistic regression with computer use does not alter the odds of reporting neck or upper extremity symptoms related to daily home computer use. The interaction of vision correction and daily computer use was not significant. Thus vision correction was related to neck or upper extremity symptoms but it was not a confounder of the effect of computer use on symptoms.

d. Handedness

Being left handed or ambidextrous was not associated with a change in odds for reporting any symptoms.

5.4.5. Combined model

In the logistic regression of home computer use frequency on neck and upper extremity symptoms, adjusted for gender, age and race, the OR for daily home computer use is 1.7 and the OR for gender is 1.6, as reported earlier. The interaction term of computer use and gender is not significant (OR=1.1, p=.99).

When all 4 electronic risk variables were entered into a logistic regression equation along with and exercise and the two other predictors identified (overweight status and vision correction) in backwards stepwise regression (p for entry=0.05, p for removal=0.1) with race, gender and age forcibly entered, only daily home computer use, risk of overweight, vision correction and gender are significant predictors of symptoms in the neck or upper extremities. Table 39 shows the odds ratios associated with this model.

Table 39. Odds ratios for reporting neck or upper extremity symptoms by all significant predictors, adjusted for age, race and gender

Predictor variable	OR (95.0% CI)
Daily home computer use	1.9 (1.2-2.9)
Wears glasses or contact lenses	1.7 (1.1-2.8)
At risk of OW or OW	1.7 (0.97-3.0)
Gender – Girl compared to boy	1.8 (1.1-2.8)
Age – continuous	0.90 (0.79-1.0)
Race – White compared to nonwhite	0.81 (0.47-1.34)

When all the second order interaction effects among the significant predictors are entered in a backwards regression, daily computer use, overweight status and vision correction terms remain in the model, but not the terms with gender.

None of these models predicts the likelihood of symptoms very well. The exhaustive model with computer and game use, exercise, demographics, overweight status and vision correction (step 1 in the backwards regression) correctly predicts presence or absence of neck or upper extremity symptoms 65% of the time, while retaining many insignificant variables. The model with significant main effects only (computer use, overweight status, vision correction and gender) correctly predicts symptoms 60% of the time, with or without interaction terms. The model with home computer use frequency, gender, age and race predicts symptoms correctly 59% of the time. Thus although home computer use, gender, overweight status and vision correction are associated with the reporting of neck or upper extremity symptoms they do not comprehensively account for the occurrence of these symptoms.

Chapter 6 Discussion

This chapter begins by assessing the evidence for the three study hypotheses. The hypotheses are discussed separately, including supporting and contradictory results, ending with a summary of the findings for each. Next, potential confounders and effect modifiers are addressed. The research questions are reviewed and the combined model is then described. A discussion of the study limitations follows, concluding with recommendations for future research.

6.1. Assessing support for study hypotheses and research questions

6.1.1. Hypothesis 1: Children who use computers and electronic devices more frequently will experience higher rates of neck or upper extremity musculoskeletal symptoms than children who use them less or not at all

Daily home computer use was associated with increase in reporting of symptoms in neck and upper extremities

In the unadjusted and adjusted binary logistic regression analysis, daily home computer users were significantly more likely to report pain or discomfort symptoms in the neck or upper extremities, compared to less than daily user and compared to those using weekly or less. The odds of reporting neck and upper extremity symptoms of medium intensity or greater, and weekly or more often, were also increased in the daily users compared to less frequent users. Thus daily computer use was associated with increased odds of neck or upper extremity symptoms occurrence, of more intense symptoms and of frequent symptoms. Gender was an independent predictor of symptoms reporting, but the effect of daily home computer use was not different in girls and boys.

Notably, the negative impact on neck or upper extremity symptoms was seen primarily with daily computer use, rather than as a linear relation with increasing use from never to daily or almost daily (5-level scale) or as a trend across the low, moderate and frequent categories used in the logistic regression. Although the test for trend across categories of use was significant for marking neck or upper extremity symptoms on the body map and for symptoms of medium or greater intensity on the scale, in all cases the odds ratios for 2-3 times per week compared to weekly or less were slightly less than 1, and not significant. This lack of effect at moderate levels of exposure may be because recovery from the relatively minor trauma caused by repetition and static strain is likely after a day or more of rest between exposures.

Other electronic device use frequency was not related to neck or upper extremity symptoms

It was expected that handheld and TV-based game use would contribute to the reporting of upper extremity and neck symptoms. This result was not seen. There are several possible explanations for this.

The prevalence of symptoms in the population may have made establishing an association difficult. Hand problems and impingement syndromes are the symptoms most commonly reported anecdotally in relation to TV-based game use (Cleary, et al., 2002, Macgregor, 2000, Reinstein, 1983, Tazawa, et al., 1997). As hand symptoms were relatively rare in this population, a much larger sample may be required to identify any association with game use.

It highly possible that the postural demands associated with TV-based or hand-held games are so variable between subjects that specific effects are washed out. For example, for some users a monitor may be on a shelf while the user sits on the floor, but for others a more mechanically supported position may be attained by sitting on a couch. It is also possible that the postures adopted by each subject while using game devices are such that little cumulative biomechanical demand is experienced. Children are notably more mobile in many activities. While this is often called fidgeting, and discouraged, it may protect children against the stresses of sustained static postures. A cross sectional survey cannot record this behavior.

In addition, patterns of use may be different from that associated with computers – sessions may be shorter or more broken up by other activities, and more shared gaming could encourage overall movement. Even the notable differences in attention and arousal between active games and more passive reading or Web surfing could have different effects on musculoskeletal symptoms. Finally, the relatively small amount of handheld game use, and the decline in use with age for both game types suggests that this older group was not the right population to evaluate for the impact of game devices.

Symptoms in areas other than neck or upper extremities were not related to computer or electronic game use

Computer use frequency did not significantly predict symptoms in any body part outside the neck or upper extremities, when adjusted for gender, age and race. This lack of association between computer use and symptoms beyond the specified area of the neck and upper extremities expected to be affected by computer use further supports hypothesis 1. It indicates that the relationship discovered here was not simply an increased association between computer use and symptoms reporting in this population. It also supports the belief that computer use affects a sector of the body rather than a single part. The impact of computer use may be located differently in different users, because of physiological, anthropometric or behavioral differences. A much larger study may be needed to identify any increase in symptoms in single body part such as the hands, shoulder or neck.

However, daily TV-based game use and daily TV watching were associated with mid back symptoms. A similar effect has been shown by other researchers (Balague, et al., 1994, Gunzburg, et al., 1999).

Summary of findings related to hypothesis 1

These findings support the major hypothesis of this project, that daily computer use is associated with neck and upper extremity symptoms in middle and high school aged children. The effect was notable in those using a computer at home daily or almost daily. These daily computer users were more likely to report experiencing symptoms in the past month, to classify symptoms as medium or greater and to report more severe symptoms (combining intensity and frequency). School computer use and electronic game use frequency were not associated with increased symptoms. The effect of daily home computer use is moderate in the group overall (OR= 1.5-1.7, $p<0.05$). The effect was larger in high school students (OR=3.2-5.0, $p<0.05$) than middle school students (OR=2.5, 0.96-6.2) in one middle school but not significant in 2 middle schools.

6.1.2. Hypothesis 2: Children who use computers and electronic devices for longer periods will experience higher rates of neck or upper extremity musculoskeletal symptoms than children who use them less or not at all.

Longer daily use was not associated with neck or upper extremity symptoms

Although total daily use may seem a more likely significant predictor of symptoms than frequency, as indicating a more sustained demand, the analysis of daily time variables did not reveal an association. Those using computers or electronic games for longer on an average day did not experience increased symptoms in the neck or upper extremities.

The failure to demonstrate an effect of increased total daily use could be because it is harder to estimate time than to approximate frequency. Subjects may underreport or overreport duration. If this misclassification is non-differential with respect to outcomes it is likely to bias findings towards the null, producing the negative findings seen here. Time might be so variable from day to day for any subject that a single estimate cannot provide a real measure of exposure. Valid time variables may require a more objective and responsive reporting format such as a diary or an electronic counter.

Longer home computer use without a break was associated with neck or upper extremity symptoms

Increased duration of home computer use without a break increased the odds of reporting neck or upper extremity symptoms. These results support hypothesis 2, but the expected trend across intervals was not observed. This may be because of the large range in exposure included in the middle category (0.5 to 1.5 hours). A continuous or otherwise more sensitive measure might describe this relationship better.

Age at first use was not consistently associated with neck or upper extremity symptoms

In this population neither age at first use nor years since first use was associated with symptoms reporting, for computers or for handheld games. The was a small increase in odds with increasing years of TV-based game use.

The lack of consistent association could be simply because duration in years does not reflect physiologically relevant exposures – you could be a long time computer user and not spend much time on it or use it frequently. This relatively young group may not yet have passed a latent period for the development of symptoms. Because they are at different stages of physical development, electronic device use may affect people differently as they grow. Finally, kinds of use (e.g. games vs. surfing), equipment design changes and other secular trends could interfere with a good assessment of the impact of longer years of exposure. However, years of cumulative use remains a potentially important risk factor and should be assessed in future research.

Potential explanations for the limited relationship between time measures and symptoms

The ecology of use (intensity, number of breaks, duration) may differ between daily and less frequent users. In this sample, the mean scores for duration of weekend or weekday home computer use were significantly greater in daily users than in less than daily users. Although time in hours per day as measured in this survey was not a significant predictor of neck or upper extremity symptoms, it logically should play some role in the association between use and symptoms.

There may be different effects of computer use time versus frequency on different body areas, perhaps related to the different effects of static compared to repetitive stress. In a recent review, arm and hand symptoms but not shoulder and neck symptoms were related to time of use (Gerr, et al., 2004). The reviewers suggest, "These differences may indicate true biological differences in the effect of computer use on hand/arm and neck/shoulder MSD outcomes." In the current study, the low rates of hand and arm problems and the relatively limited times reported may have obscured this differential impact.

Summary of findings related to hypothesis 2

Hypothesis 2, that those using computers and games for longer periods are more likely to report neck or upper extremity symptoms, is supported by the results for increased home computer use duration without a break.. However, increased daily time alone was not a significant predictor, nor was years of use except for TV-based games. Increased electronic game and school computer use times do not increase symptoms reporting.

6.1.3. Hypothesis 3: Children who use computers and electronic devices in more awkward or uncomfortable postures will experience higher rates of neck or upper extremity musculoskeletal symptoms than children who use them in neutral postures.

Equipment positions were not consistently associated with neck or upper extremity symptoms, but foot position and mouse position show some association

More demanding equipment position was not related to increased symptoms reporting in the group overall. This could be because of a lack of association, or because of measurement failures described in the section on survey limitations below.

It could also be that the load associated with each position is different for computer and game users. To assess this, equipment information was split into predominant game users and predominant computer users. In computer users, foot position was the only postural variable that was even marginally associated with neck or upper extremity symptoms reporting. The odds ratios for all other categories compared to “feet easily reach the ground” range from 1.9-5.4 (p=0.06-0.1, but the 95% confidence intervals were quite large in 2 of the three cases, indicating instability in the estimates). This could mean that unsupported or constrained foot position when using the computer is consistently demanding, while the demand from other equipment positions is mixed. It could simply be that those who cannot put their feet on the ground are also experiencing other biomechanical demands, more directly linked to the upper extremities, such as reach or neck angle. There was no difference in mean height among foot position groups, so the difference is not likely to be due to position differences relative to the monitor or keyboard. The role of this variable in predicting risk needs further exploration.

Among predominantly game users, those using a control device on the lap, compared to a tray or table, were less likely to report neck or upper extremity problems. This result strongly supports hypothesis 3: reaching out or up to use a control device is likely to put demands on the shoulder and arms, as well as lead to extreme angles at the shoulder, elbow and hand. Thus for gamers the placement of the control device closer to the body may be a key element in controlling symptoms.

Summary of findings related to hypothesis 3

Foot position among computer users and control device location among TV-based game users were related to symptoms reporting in the neck or upper extremities. These findings, as well as the lack of association between symptoms and the other variables, could be due to the limitations in the instrument described below.

6.1.4. Research questions

In addition to identifying associations between neck or upper extremity symptoms and computer and game use and exploring the size of the associations, this study was designed to identify habits or characteristics that aggravate or protect against the effects of electronic device use. These factors are described below.

The effect of daily home computer use on neck or upper extremity symptoms was different in different grades or age levels

When the group was stratified by age or by grade, it was clear that daily home computer use was associated with neck or upper extremity symptoms mainly in the high school group and was not significant across the middle school students.

Age differs from grade level because some children start school late or are held back. Although all high schoolers (ninth grade or above) were at least 14, 8% of the middle school subjects over 14. All 11-12 graders were over 16, but 22% of the 9-10 graders are16 year or over. Thus stratifying by age is slightly different from stratifying by grade, and produces different results. The odds ratios for reporting neck or upper extremity symptoms related to daily home computer use for 9-10 graders were the same as those for 11-12 graders. In the similar but not identical division by age, the odds ratio for the 16-18 year daily users was double that for the 14-16 year olds. In both younger groups (7-8 graders and 12-13 year olds) the odds were not increased with daily computer use. Controlling for age in continuous years or in three age categories does not attenuate the relationship between home computer use and symptoms. However, the interaction term (age level*daily home computer use) is close to significance when entered into the logistic regression equation with home computer use frequency, age, gender and race. Although computer use frequency does not change directly with age, there may be an interaction in terms of the effect of use frequency on symptoms.

There are several possible explanations for the effect of age on computer-related symptoms. Age, though not directly related to increased symptoms, could modify the impact of computer use in physiological, anthropometric, behavioral or differences between the age groups, or even differences in the way they approached and responded to the survey.

The high schoolers and the middle schoolers may have responded differently to the survey, demonstrating more or less systematic error in their answers and obscuring real similarities in the exposure and outcome relationships. They may engage in computer use differently, or in other activities, not measured here, that affect symptoms. They may experience microtrauma or healing at different rates.

The difference could be between age, grade or school level. It is possible that the increasing association between computer use and symptoms with increasing age results because age and school level (high school vs. middle school) were highly correlated, and that the true relationship is more directly related to school demands. High schoolers may use computers differently than middle schoolers do. This could be because of leisure use patterns or schoolwork done at home. So for example, high schoolers might do more research and writing compared to surfing and games, thereby affecting biomechanical or psychosocial demands.

Exercise might moderate the effect of computer use

The odds of reporting neck and upper extremity symptoms were not significantly increased in daily compared to less frequent home computer users if they also reported vigorous daily exercise (adjusted OR=1.4, p=0.3). Less frequent exercisers were still at increased risk if they used the computer daily compared to 2-3 times a week or less (adjusted OR=1.9, p=0.01). Although the difference is not great, and the interaction term was not significant, it is possible that daily exercise may limit the impact of daily computer use.

This relationship was not an artifact of differences in computer use time. Daily and less frequent exercisers do not differ in home computer use frequency, in duration or typical daily time of computer use, nor total computer use time per week combining home and school use. The correlation between frequency of home computer use and frequency of exercise was very small and not significant. Computer time was not associated with exercise time estimates. Daily computer users were not less frequent exercisers. Thus daily exercise does not protect by reducing the time spent on the computer. This finding is supported by other recent research (Feldman, 2004).

Daily exercise was not independently associated with reduced symptoms reporting. Exercise does not seem to directly reduce symptoms reporting in this area, but it may act in some way on the path from computer use to symptoms, as an effect modifier. The lack of relationship between exercise and symptoms may be an artifact of the general definition of activity used in this study ("How often do you exercise or play hard (enough to make you sweat or get a little out of breath)?"). It is possible that some portion of the daily exercisers engage in sports that increase the risk of musculoskeletal symptoms, and some do not. The competitive ball players, for example, may have higher rates of shoulder symptoms, enough to hide a true protective effect of exercise overall. By failing to record this, the current survey format could produce misclassification of subjects in terms of overall musculoskeletal risk exposure.

Interestingly, when overweight and exercise status were both included in the regression equation along with age, race and gender, exercise becomes significantly protective for neck or upper back symptoms and for midback symptoms. Clearly a complicated relationship between exercise and overweight status exists that must be elucidated with a more sensitive instrument.

It could be argued that children who experience pain are less likely to participate in sports, or perhaps they have weak arms, shoulders or hands, do worse at sports and thus choose to participate less. If this were the case, any observed protective effect of sports would not be physiological but a result of subjects predisposed to pain opting out of physical exercise and filling their time with computer use. If exercise were a confounder in the relationship between computer use and symptoms, the results would seem to support an association but the causal link would be reversed – instead of more exercise leading to fewer symptoms among computer users, more symptoms would lead to less exercise and concurrently more computer use. The results described here do not support the role of exercise as a confounder, as exercise was not related to upper extremity symptoms and computer use and exercise were not negatively correlated.

Vigorous daily exercise could counteract the deleterious effects of computer use in a variety of ways. Increased cardiovascular fitness could be a factor in reducing the experience of pain or discomfort. Even short-term increase in circulation or reduction in muscle tension related to exercise could limit the effects of static strain or edema. Regular exercisers may have more stable joints, making them less vulnerable to the low-level biomechanical demands of computer use. Finally, more active people may use the computer in a different way, perhaps moving more while they sit, adopting different postures or using the computers for shorter periods without a break. (It should be remembered, though, that vigorous activity might also strain, statically or dynamically, the areas at risk through computer use.)

Whatever the reason, a possibly attenuating effect of daily exercise provides guidance on developing a reasonable and effective campaign to ward off the development of computer-related symptoms and syndromes in children, adolescents and young adults. The potential impact of exercise as an effect modifier is especially important in the context of the trend of decreasing rates of regular exercise in this population as described by Anderssen (Anderssen et al., 1996), and others (CDC, 1996) as computer use increases. This study design cannot establish a directional or causal link between exercise and computer use, because symptoms and exposures were measured concurrently. However the combined pressure of increased computer use and reduced exercise over time and with age should be of concern. The association between increasing age and decreasing daily physical activity seen in other studies (Anderssen et al., 1996) suggests a role for schools in ensuring that students remain active by providing regular opportunities for physical activity, encouraging participation at all age levels and perhaps increasing required physical education class frequency.

Undercutting the value of the link between exercise and a moderated effect of computer use, when subgroups were analyzed this apparently protective effect of exercise disappeared. For example, when the analysis was limited to the 364 subjects who reported enough data to allow BMI calculations, the adjusted odds ratios for reporting neck and upper extremity symptoms related to frequency of computer use were the same magnitude in daily and less frequent exercisers. This was also the case if only subjects using computers more than weekly were assessed. Reporting bias could have led to an apparent though false effect modification (Rothman, 2002, p.353), revealed in these stratified analyses.

The effect of exercise was not significant. It may be only an artifact of data collection, it may point to group differences that require further analysis, or it may indicate a true mediator of the negative impact of computer use.

Weight status was associated with symptoms

Although BMI was not initially proposed as a confounder nor as a primary cause of musculoskeletal symptoms, recent literature suggests that it may be associated with video game and computer use (Vandewater, et al., 2004). However, in this study overweight status was not associated with computer use.

Overweight risk (defined as BMI for age and gender >85th percentile) was associated with symptoms reporting in some areas. Those at risk of overweight were significantly more likely to report symptoms in the neck or upper extremities compared to those not at risk. The odds of reporting arm or elbow symptoms were higher in the heavier subjects.

More boys than girls reported BMIs greater than the 85th percentile for gender and age. They might in fact be more overweight than expected. The disparity could also occur if overweight girls were more likely than boys to underreport their weight, or simply did not report and thus did not appear in the analyses that depended on weight. This differential response could affect the odds ratio. In addition, the meaning of overweight risk status may differ between the genders: Boys in this population may have more muscle or bone mass relative to the norm, rather than more fat.

It should be noted here that there were only 41 subjects at risk of overweight and 34 in the overweight category, so notwithstanding the statistical significance the results may not be important.

Despite these limitations, overweight status remains a significant predictor for neck and upper extremity symptoms when entered with home computer use frequency and controlling for gender, age and race. The odds of reporting neck or upper extremity symptoms were not affected by including it in the regression equation. Thus overweight status seems to have a complex relationship with symptoms reporting, but is not a confounder of the effect of daily home computer use.

Race and gender were not confounders

Race and age were not associated with neck or upper extremity symptoms. They do not affect the relationship between computer use and symptoms reporting in this area. However, they were retained in the analyses because of their association with some symptoms and some activities in the literature and in the current results.

Aside from increasing age, being a girl was the only predictor of low back symptoms. This finding is consistent with other research (e.g. Balagué, et al., 1999). Being a girl was associated with increased symptoms in most areas but notably not in the lower extremities; only daily exercise was strongly associated with symptoms in this area. Race was not associated with increased risk of reporting any symptoms. The lack of variation in race may have obscured any association. Further research should oversample underrepresented race groups to clarify this question.

Sedentary behavior considered as an alternative explanation

Reading and television watching might be considered equivalent to computer use in that they are sedentary. Reading was associated with an increase in symptoms in the shoulder. No other symptoms odds were significantly different for reading. Daily compared to less than daily television watching was associated with increased midback symptoms, but not neck or upper extremity symptoms. These findings suggest that it is not simply the sedentary nature of computer use that leads to the observed association with neck and upper extremity symptoms. Other research supports this, finding no consistent limitation of social or physical activity with increased computer or Internet use (Robinson, 2002). One study suggested that young people who participate in productive sedentary activity, such as reading and computer work, report increased physical activity (Feldman, et al., 2003). Like this study, Feldman found no association between television or video game use and level of physical activity.

Discomfort as a cause rather than a result of behavior

It is conceivable that the experience of pain or other symptoms affected how often or for how long computers were used. Past users who developed symptoms might start using computers less (or, counterintuitively, more) as a result. If surveyed before computer-related symptoms went away they would seem to be symptomatic with less computer use, reducing the association of symptoms with exposure. To evaluate this possibility, the survey asked respondents to state whether they had changed any of their computer use, electronic game playing or other physical activities. The odds ratio related to daily computer use for those who reported no change in any activity related to symptoms was virtually the same as for the group as a whole, suggesting that modifying behavior did not affect the association. In any case, reduced activity following symptoms related to the activity might be expected to attenuate an observed effect, because those with symptoms and reduced current exposure will be misclassified for relevant exposure.

6.1.5. Combined model for neck or upper extremity symptoms reporting

Home computer use frequency, gender, overweight status and vision correction were the only significant predictors for neck and upper extremity symptoms identified in this study. The odds ratios in each case are about 1.7 when they are all included in the regression equation. Age, race, exercise and other electronic device use do not contribute significantly to the logistic regression model.

The direction of the associations has not been established. A variety of physiological, biomechanical and psychosocial explanations could be brought forth to explain a causal relation between computer use - or overweight, or vision correction - and symptoms. What is most interesting, in view of potential prevention efforts, is that computer use and weight are amenable to change, rather than immutable characteristics such as gender. If frequent and sustained computer use contributes to these symptoms, young users can be limited in computer access time, and encouraged to take breaks and otherwise reduce their risk. If overweight causes increased musculoskeletal symptoms, this is all the more reason to teach children and teens to control weight gain. Vision correction, though not changeable, points to important aspect of posture and the relationship between computer use and vision. More information about the patterns of use and symptoms is needed before specific time limits are established or equipment set up or design recommendations can be made.

6.1.6. Summary of findings related to research questions

In this population, home computer use was the only significant electronic predictor of symptoms in the neck or upper extremities. The effect size of daily home computer use – almost a doubling of odds in the most frequent users overall, and a 3-fold increase in high school subjects - was high enough to be of concern. Frequent exercise may be protective.

The model developed here does not do very well in predicting whether a subject will report symptoms in the neck or upper extremities. The myriad other contributors to pain reporting continue to be important. However, if young people do report symptoms, it makes sense given this data to investigate and perhaps modify their computer use. Similarly, heavy computer users should be alerted to the potential problems and trained to change some of the things that make their computer use risky.

6.2. Study limitations

6.2.1. Clinical significance of findings

An essential weakness of the self-administered questionnaire is that it cannot adequately assess clinical status. This is particularly an issue in this population as adolescents are even less likely than adults to have been examined by a health care provider for musculoskeletal conditions. Few respondents reported clinical musculoskeletal disorders. However, 11% of those with neck or upper extremity symptoms reported seeking medical care and 28% used medications for the symptoms. These symptoms caused 9% to limit computer use and exercise, and 8% to miss school.

Although an attempt was made to assess the importance of the symptoms reported, the symptoms severity measure produced by combining the intensity and frequency variables did not result in an easily interpretable measure. Effectively recording the duration and severity of symptoms, including those approaching clinical syndromes, demands a longer-term assessment of musculoskeletal health in this population than was possible in the current study. A study of the clinical impact of computer and game use should be done in a larger population to achieve adequate power to identify changes in proportions of fairly rare diagnoses, and to take other health problems and subgroup differences into account.

The concern remains that even sub-clinical symptoms developing at younger ages can have a negative impact on youth as they enter college and then the workforce. If exposures and symptoms increase as students grow up, as some evidence suggests they will (Katz, 2000, Peper, 2000), colleges and employers of young people could be dealing with a costly epidemic of computer-related disability.

6.2.2. Distribution

The overall response rate was 75% of the recruited subjects. Losses were seen mainly in HS1, where only 44% of these 11-12 graders provided usable data. This occurred because the students, instead of receiving the survey in a mandatory homeroom class as in the other 4 schools, were issued hall passes and many chose not to show up. The refusal rate was also higher in this group, with students typically explaining that they could not afford to miss their currently scheduled class.

Of the completed surveys, 16 (3%) were unusable because of consistently spurious results. Ten of these were in HS1, where the survey distribution session was not supervised by any school staff.

The limited response in HS1 highlights the need for rigorously enforcing the planned distribution method, which was otherwise quite successful. The principal in the school explained that he was helping us get a better sample, however without supervision the students did not cooperate. Notwithstanding these lost subjects, the logistic regression analysis produced odds ratios for neck and upper extremity symptoms reporting in relation to home computer use frequency that were consistent with the more successful recruitment in the grades directly below. This encourages confidence that the losses were not differential with respect to exposures or symptoms.

Gender or race was not reported by 40 subjects, which eliminated these from all adjusted analyses. Height or weight blanks excluded a further 23.5% from analyses including overweight status. However, the results for the association between home computer use frequency and neck or upper extremity symptoms for the adjusted analyses were consistent with the unadjusted results, suggesting that these losses in power have not obscured important associations.

6.2.3. Survey weaknesses

Activity items

The self-report measures used in this survey have not been validated through observation or any form of objective measurement in this population. This problem is not unique to the younger population: an extensive review of reliability and validity of work-related assessments reported, “Most work-related assessments have limited evidence of validity” (Innes and Straker, 1999, Innes and Straker, 1999).

This lack of validation has been an issue in other research that depends on self-reported activity (Kohl III, et al., 2000). One children’s activity research team was not unduly concerned, reporting of an activity questionnaire they developed, “We believed that this questionnaire was reliable and valid because the questions were straightforward and easy to understand" (Newcomer et al., 1997).

Such a confident claim cannot be made for the current study. Because of the limited evidence for validity of activity items, the associations reported here must be qualified as applying to those who report behavior frequency and times, not those who in fact experience them. The quantitative relationship between reported activities and actual exposures remains to be established.

Measures such as keystroke counters or other use timers might provide more quantitative measures of use. However they are also likely to be difficult and expensive to implement in a large population. Making sure that only the subject’s use was measured, and that subjects did not use unmonitored equipment would be very difficult. Monitoring is likely to be noticed by users, possibly affecting use. Furthermore, monitoring may pose privacy concerns that would demand a higher level of human subjects and consent protections.

Specificity of exposure questions is also a concern. The survey did not distinguish between different types of content or activity (e.g. web surfing, word processing, chatrooms were not recorded) because of limited variability in response in the field trials and limited evidence about the direction and size of any potential impact of these variables. Among adults, organizational demands and work stresses have been associated with musculoskeletal disorders (Huang, et al., 2003, Wahlstrom, 2005). It is certainly possible that differences in cognitive or psychological demand between these activities and between subjects could affect the probability of negative outcomes.

Bias in exposure may have occurred. Although self-report probably results in overestimation of exposure, it could be argued that as long as comparison is between subjects using the same survey this should not produce erroneous associations among relative levels of exposure (Welk, et al., 2000). There is a concern that subjects providing both symptoms and exposure data through this self-report survey format may lead to misclassification of exposure based on common-instrument bias. Common-instrument bias is defined variously as "potential information bias arising when the subject reports both the outcome and the exposure" (Palmer, 2004) and as "The notion that a worker's perception of high exposure status might lead him/her to report higher symptoms status, or vice versa" (Occupational Safety and Health

Administration, 1999). However, the effect observed in this study was very specifically restricted to home computer use frequency and neck or upper extremity symptoms. No association with these symptoms was seen for any of the exposures except computer use, whereas if bias was present it should also be expected for game use or perhaps exercise. This suggests that common-instrument bias is not a large concern in analyzing this data.

Precision may be lost when using forced categories for time estimates. An open-ended time format was used in the initial stages of the survey. Subjects commented at the time that they could not give a precise number of minutes, so a question based on ranges was considered less onerous and more likely to be answered. In any case, given the variability in times from day to day, and the difficulty of recalling or even noting duration of activities, any self-reported time estimate is not likely to reflect precise time measurements. Again, if the response is non-differentially imprecise with respect to symptoms the measured associations should be underestimated. Otherwise the direction of the error cannot readily be predicted.

Postural items

The postural measures were certainly the least tested and probably the least reliable section of the survey. Other research has shown low to moderate success in getting even adult workers to report on postural demands (Mortimer, et al., 1999, Torgen, et al., 1999). Subjects in the CAUTS survey pilot studies were unable to describe their own postures while being observed. In addition, because posture changes frequently during computer use, simple posture questions are particularly difficult to answer.

Thus in this study equipment position was used to estimate posture. However, the equipment positioning items were not a good way to measure postural risk for several reasons. The items were designed to establish a gradient of exposure within the first three responses, with the fourth question an equivocal or neutral position. They could typically do so only in one dimension for each piece of equipment. An additional problem was that the equipment items applied predominantly to computer use rather than TV-based or hand-held games. This was not a sensitive measure of exposure as use habits and postural opportunities diverge widely between computer users and game users.

Equipment placement is only a very rough proxy for musculoskeletal demands. For example, typically the higher the monitor the more neck strain and potentially other problems. However, knowing that the monitor is on the desk does not mean that it is low enough, nor indeed that it is not too low. The same holds true with the use of a keyboard tray: while it can be expected to be better than using the desktop for keyboard or mouse, a nonadjustable keyboard tray or one at the wrong height or angle does not create an adequate workstation.

Indeed, an apparently adequate posture in one dimension could indicate a very bad accommodation overall. For example, the preponderance of subjects reporting that their feet reach the ground may sit this way only because their chairs are too low relative to the monitor or keyboard level. More important for hand symptoms, the use of a small or nonadjustable keyboard could force the mouse to be placed a higher or to the side. And an apparently adequate workstation at one age could be too large when younger, too small when older, or otherwise ill-suited to the changing size and habits of the subjects in this age range.

Some researchers ask about the presence of adjustable equipment as a marker of ergonomic sufficiency of the workstation (for example, Jacobs, 2002). The question was not asked in this survey because it does not provide information about whether the workstation is appropriately adjusted for the user. In addition, few workstations for children are likely to be appropriately adjustable.

These questions represent the early stages of developing an effective measure for self-reported biomechanical demand. They are based on the belief that equipment constrains posture. However, the relationship between the equipment locations and an identifiable biomechanical demand or a predictable musculoskeletal effect was not well established. This problem has been noted in research on adult computer workstations as well (Gerr, et al., 2004), and effectively described as follows: “The relationship between equipment location and biomechanical demands is not direct; it is mediated by posture, which in turn is determined by personal factors such as anthropometry. The biomechanical demand of a posture is clear, and the relationship between posture and workstation design is also clear. It is the relationship with MSDs that is confounded by other factors such as usage. Unfortunately, many epidemiological studies do not use tools that take these factors into account in the exposure measurements.” (Halpern, personal communication). Gerr has described the immense difficulty in mapping specific postures on to computer configuration, suggesting a principal components analysis in defining postural risk factors (2004).

Population studies based on self-report such as this one can provide guidance about potential associations but not well-specified exposure measures and hence outcomes associations. Methods for self-report of posture and collection of field data should be developed and tested in children and adolescents. Perhaps family members could be trained to carry out sampled observations. It is most likely that assessing biomechanical or postural strain related to computer and game use will best be carried out through intensive professional observation and through laboratory studies such as those being done in Australia (Briggs, et al., 2004, Straker, et al., 2002, Straker and Pollock, 2005, Zandvliet and Straker, 2001).

Symptoms items

Symptoms as assessed using the body map do not provide information about severity or clinical significance. Other researchers have asked about symptoms occurring at least weekly or lasting for a defined time (Egger, et al., 1999, Feldman, et al., 2002) . The purpose is to avoid recording transient or very mild symptoms, which are not likely to reflect longer-term musculoskeletal problems,.

Through an oversight, the scales for symptoms intensity and frequency do not match the coding used for the body map reporting of symptoms experienced in the past month. Neck and upper back were combined in the scales, and midback was not included. This error in editing made comparing results from the two formats somewhat difficult. However, the association between computer use frequency and neck or upper extremity symptoms of medium intensity or greater was very similar to that of neck or upper extremity symptoms reported on a body map. In this survey, reporting neck or upper extremity symptoms in the past month on the body map corresponded fairly well to reporting neck, upper back or upper extremity symptoms as medium or greater on the intensity scale (Kappa=0.56, p<.001). There was significant agreement between those marking each area on the body map and any symptoms in the corresponding intensity scale ((All Kappas>0.30, p<.001), as well as those marking any area of the body map and those marking any symptoms on the intensity scale (Kappa=0.58, p<.001).

Potentially important contributors not assessed

The purpose of the current study was not to exhaustively evaluate the range of causes of musculoskeletal symptoms, nor to test a myriad of possible associations. Variables were limited to physical activities and likely demographic confounders. Thus, for example, familial factors were not assessed, as they did not have any apparent association with the computer-related risk factors of interest.

Socioeconomic status may also be a predictor of both symptoms reporting (Rhee, 2003) and activity, including computer and electronic game use (Linebarger, et al., 2004, Wartella, et al., 2000). The school district surveyed has a lower family income than the state as a whole and compared to national figures (Bureau of Labor Statistics, 2005, State of Connecticut, 2002). However, to keep the survey as userfriendly as possible, financial questions were not asked. The same is true for other potential predictors of musculoskeletal symptoms such as smoking, which has been related to back pain in adolescents and adults: subjects do not want to answer these questions, and including them could impair the value of other data by alienating respondents.

Other important predictors of symptoms reporting including psychological status were not assessed as they were not theoretically or empirically linked to the study hypotheses. Specific pre-existing illness such as diabetes or autoimmune disorders, while potentially confounding, were not recorded, because advice early in the survey development process suggested that subjects would find such questions intrusive. Although some information about illness was provided in the questions on seeing a doctor and on causes for symptoms, they were not sensitive or detailed enough to identify risk subgroups.

Work experience and specific workplace exposures were not recorded. In retrospect this was a definite error, given the association between teen work and musculoskeletal symptoms that has since been reported in the literature (Chapman, et al., 2003, Feldman, et al., 2002, Siivola, et al., 2004). Perhaps the biggest void was the absence of items concerning text messaging. This activity was not as common during the survey development period as it now seems to be in this age group. There are indications that use of text messaging is frequent and on the increase in adults and in adolescents. A sociologist quoted widely in the press has suggested that notable changes are occurring in hand structure and dexterity, with thumbs being used so frequently . (The researcher did not provide evidence on the frequency of the change nor of their relationship to musculoskeletal symptoms.) Case reports of severe symptoms related to text messaging have been described in medical and popular media (Reuters Health, 2005, Yoong, 2005).

Work, text messaging, and health, social and psychological factors are all potentially important contributors and should be analyzed in the next stage of research in this field.

6.3. Implications of findings

This study establishes baseline measures of symptoms and exposure in a late childhood and early adolescent population and identifies associations between use, symptoms and other contributing variables. Whether the symptoms of pain and discomfort experienced at this early age are related to the development of clinical syndromes or long-term health problems is not clear.

Many factors, recognized and unknown, physical and psychological, contribute to musculoskeletal symptoms reporting in children as well as adults. Some (such as gender) are immutable, and others (such as overweight) are likely to be intractable. Changing early patterns of computer use could be an important avenue for limiting musculoskeletal symptoms in childhood, and perhaps the development of longer-term problems in college and in working life. Understanding the postural demands related to computer and game use should suggest improvements in technology and furniture design.

6.4. Suggestions for additional research

6.4.1. Additional epidemiological research

Because the contributors to musculoskeletal health and development are diverse and complex, it was important to begin with an understanding of the epidemiology of computer use and musculoskeletal symptoms. A cross-sectional analysis of current rates of use and the association with musculoskeletal symptoms was an essential first step. Confirmatory studies in other settings should follow. A longitudinal evaluation of physical development as it relates to computer use is necessary. Future research will need to take into account the baseline levels of symptoms reporting, by gender, age, ethnicity and weight for height and age, especially as computer use and other activities are also affected by these characteristics.

Barrero and Hedge (2000) and others have described some of the research considerations that should guide other studies. More objective data collection methods should be developed, and the validity of self-reported exposure and symptoms in this population confirmed. Operationalizing the biomechanical and physiological demands of computer use and game use distinctly, given the wide variety of exposure settings and use habits, will be a challenge to researchers.

Perhaps most important to understanding the impact of computers and other devices on children and adolescents is a comprehensive ecological description of how they use these things. What is the ergonomic environment - furniture, equipment placement, input device design? How does this differ while playing games, when using notebook computers? What postures and movements are adopted? How long are activities or postures maintained? What do children do that might in fact be protective—stand up, share tasks, work in spurts, for example? And what makes them feel more comfortable? Adults may be able to learn about better computer use behavior and conditions from children.

The ergonomic environment is a critical component in evaluating and predicting risk (Freedman and Perry, 2000). The types of use (gaming vs. writing, chat vs. surfing) are potential modifiers of risk, and should be evaluated. The varied cognitive and psychosocial demands related to schoolwork, gaming and socializing using computers present important arenas of investigation. This could be especially fruitful research given the increased risk of symptoms related to computer use observed in high school subjects, and the independent risk related to being a girl.

Further work is needed concerning the impact of handheld or TV-based game use, as well as text messaging and other developing technologies that create related biomechanical or physiological demands on young users.

Additional contributors, negative or positive, are likely to play very important roles in determining musculoskeletal health. It is important to explore what levels of physical activity or general fitness might protect against musculoskeletal injuries by enhancing aerobic health, and what more intensive activities such as competitive sports or dance performance might be associated with increased musculoskeletal problems in adolescents (DiFiori, 1999). Adolescents' work could contribute to cumulative trauma, and health issues such as overweight, trauma or diabetes could affect symptoms development or reporting.

Another important research consideration is whether markers for increased comfort or health are the same in children as in adults. For example, Laeser (1998) considered that longer work periods indicate improved comfort. However, whether working longer is an appropriate marker for improved comfort in children has not been established. Is pain a good indicator of musculoskeletal problems in this population, and if so how can researchers distinguish transient or trauma-related symptoms from the effects of computer use? If established clinical syndromes are considered the best indicator of musculoskeletal problems, the role of pediatricians in defining, observing and diagnosing problems related to computer or game use will need to be examined.

6.4.2. Intervention research

The classroom and home habits interventions described in chapter 1 show promise in changing perceptions and some computer use behavior. This kind of field research should continue to investigate how ergonomics skills can be communicated to children, teachers and parents; the efficacy of posture training; and the role of improved or increased physical activity in the reporting of musculoskeletal symptoms.

Equipment design improvements are a key part of ergonomics intervention in industry, and should be investigated for young computer and game users. Attempts have been made to develop and market input devices that are better suited to younger users. However no evidence has been provided to show improved symptoms outcomes or even an impact on comfort. The value of improved product design should be compared to the effect of changes in use habits.

Perhaps most intriguing, given the joint influence of computer, exercise and overweight on musculoskeletal symptoms described in this study, are the efforts to change the physical activity of computer users. A classroom program described as a “Moving School” has improved sitting posture in 8-year-old children, compared to their counterparts in traditional schools, however with no reduction as yet in back or neck pain (Cardon, et al., 2004). This concept is being applied to adults as well: Dr. James Levine and colleagues at Mayo Clinic are developing a health research and intervention program based on what they call NEAT (Non-exercise activity thermogenesis), which includes integrating physical activity into the office computer workstation set up. A final important contributor to improved musculoskeletal health in computer use would be the widespread adoption of voice-activated controls, such as Dragon NaturallySpeaking. This would reduce the dependence on mousing and keyboards and allow for more flexible and varied postures.

As computers and related devices become ubiquitous and essential aspects of home, school and work life, there will not be a better time to investigate their impact and develop plans to limit or prevent possible adverse effects. A timely investigation and programmatic response may head off a potential epidemic. Understanding the impact of computer use in children will support the development of programs to teach healthy computer use habits that may reduce problems of subsequent workplace exposure, and contribute to the design of better equipment and software. Where injury is not avoided, this understanding should also lead to improved diagnosis and treatment.

Appendices

Appendix A: Instrument

QUESTIONS ABOUT WHAT YOU DO

These questions ask about where, how often and how long you use computers. For each question, please check the box next to the phrase that best describes your normal use. Please check only one box to answer each question. Include all the ways you use a computer, including schoolwork, chat rooms, e-mail, games etc.

How often and how long do you use a computer?

1. How often do you use a computer at **school or in the library?**
- 1 Never
- 2 Less than once a week
- 3 Once a week
- 4 2 -3 days a week
- 5 Every day or almost every day

2. What is the longest time you usually spend without a break at a computer **at school or in the library?**
- 1 None
- 2 Less than half an hour
- 3 ½ to 1 hour
- 4 1-1½ hour
- 5 2 hours or more

3. How much total time do you use a computer **at school or in the library** on **an average school day?**
- 1 None
- 2 About half an hour
- 3 1 to 2 hours
- 4 3 to 4 hours
- 5 5 hours or more

4. How often do you use a computer at **home or a friend's house?**
- 1 Never
- 2 Less than once a week
- 3 Once a week
- 4 2 -3 days a week
- 5 Every day or almost every day

5. What is the longest time you usually spend **without a break** at a computer **at home or a friend's house**
- 1 None
- 2 Less than half an hour
- 3 ½ to 1 hour
- 4 1-1½ hour
- 5 2 hours or more

6. On an average school day, how much total time do you use a computer **at home or a friend's house**?
- 1 None
- 2 About half an hour
- 3 1 to 2 hours
- 4 3 to 4 hours
- 5 5 hours or more

7. On a **weekend day**, how much total time do you use a computer **at home or a friend's house**?
- 1 None
- 2 About half an hour
- 3 1 to 2 hours
- 4 3 to 4 hours
- 5 5 hours or more

8. How old were you when you started using a computer at school (if you do)? _______ years old

9. How old were you when you started using a computer at home (if you do)? _______ years old

10. How often do you play hand-held computer games like Game-boy™?
- 1 Never
- 2 Less than once a week
- 3 Once a week
- 4 2 -3 days a week
- 5 Every day or almost every day

11. What is the longest time you usually play hand-held computer games like Game-boy™ **without a break**?
- 1 None
- 2 Less than half an hour
- 3 ½ to 1 hour
- 4 1-1½ hour
- 5 2 hours or more

12. How much total time do you play hand-held computer games like Game-boy™ on an average **school** day?
- 1 None
- 2 About half an hour
- 3 1 to 2 hours
- 4 3 to 4 hours
- 5 5 hours or more

13. How much total time do you play hand-held computer games like Game-boy™ on an average **weekend** day?
- 1 None
- 2 About half an hour
- 3 1 to 2 hours
- 4 3 to 4 hours
- 5 5 hours or more

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14. How often do you play TV-based games like Playstation™?
1 Never
2 Less than once a week
3 Once a week
4 2 -3 days a week
5 Every day or almost every day

15. What is the longest time you usually play TV-based games like Playstation™ **without a break**?
1 None
2 Less than half an hour
3 ½ to 1 hour
4 1-1½ hour
5 2 hours or more

16. How much total time do you play TV-based games like Playstation™ on an average **school** day?
1 None
2 About half an hour
3 1 to 2 hours
4 3 to 4 hours
5 5 hours or more

17. How much total time do you play TV-based games like Playstation™ on an average **weekend** day?
1 None
2 About half an hour
3 1 to 2 hours
4 3 to 4 hours
5 5 hours or more

18. How often do you exercise or play hard (enough to make you sweat or get a little out of breath)?
1 Never
2 Less than once a week
3 Once a week
4 2 -3 days a week
5 Every day or almost every day

19. How much total time do you exercise or play hard (enough to make you sweat or get a little out of breath) on an **school** average day?
1 None
2 About half an hour
3 1 to 2 hours
4 3 to 4 hours
5 5 hours or more

20. How much total time do you exercise or play hard (enough to make you sweat or get a little out of breath) on an average **weekend** day?
1 None
2 About half an hour
3 1 to 2 hours
4 3 to 4 hours
5 5 hours or more

21. How often do you watch TV or videotapes?
1 Never
2 Less than once a week
3 Once a week
4 2 -3 days a week
5 Every day or almost every day

22. How much total time do you watch TV on an average **school** day?
1 None
2 About half an hour
3 1 to 2 hours
4 3 to 4 hours
5 5 hours or more

23. How much total time do you watch TV or videotapes on an average **weekend** day?
1 None
2 About half an hour
3 1 to 2 hours
4 3 to 4 hours
5 5 hours or more

24. How often do you read books or magazines?
1 Never
2 Less than once a week
3 Once a week
4 2 -3 days a week
5 Every day or almost every day

25. How much total time do you read on an average day?
1 None
2 About half an hour
3 1 to 2 hours
4 3 to 4 hours
5 5 hours or more

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26. How often do you play arcade games?
[1] Never
[2] Less than once a week
[3] Once a week
[4] 2 -3 days a week
[5] Every day or almost every day

27. How much total time do you play arcade games on an average **school** day?
[1] None
[2] About half an hour
[3] 1 to 2 hours
[4] 3 to 4 hours
[5] 5 hours or more

28. How much total time do you play arcade games on an average **weekend** day?
[1] None
[2] About half an hour
[3] 1 to 2 hours
[4] 3 to 4 hours
[5] 5 hours or more

29. How old were you when you started using a handheld computer game (if you do)? _____years
30. How old were you when you started using TV-based video game (if you do)? _____years
31. How old were you when you started playing arcade games (if you do)? _____years

QUESTIONS ABOUT THE COMPUTERS OR ELECTRONIC GAMES YOU USE

32. **Are you comfortable when you use a computer at home?** Yes No

If no, why not?____

____

33. **Are you comfortable when you use a computer at school?** Yes No

If no, why not?____

Please answer the following questions about the computer or electronic game you normally **use the most.**

34. The computer or electronic game I normally use the most is (choose one only):
[1] a desktop computer
[2] a notebook/laptop computer
[3] a hand-held game like Gameboy™
[4] a TV-based video game like Playstation™
[5] other. What is it? ____

35. This computer or electronic game is (choose one only):
[1] at home
[2] at school
[3] I carry it with me
[4] other ___________

36. How do you control this computer or electronic game (not including keyboard):
___Mouse ___Mouse pad ___Track ball ___Joy stick ___Game controller pad ___ Eraser-head
___Other: What is it? ______________________________

38. **Are you comfortable when you use THIS computer or electronic game?** Yes No

If no, why not?____

____

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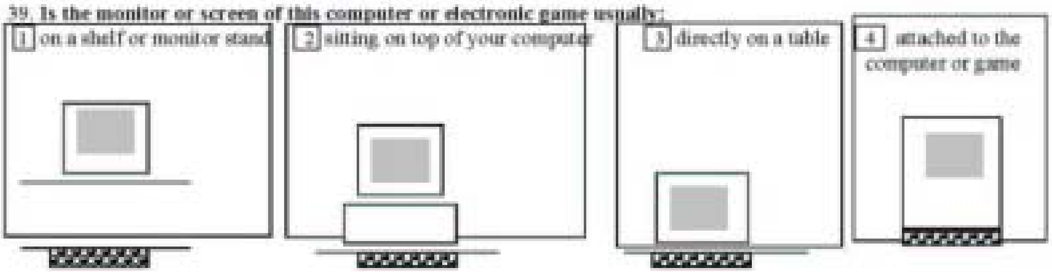
37. Please mark how often you use the computer or electronic game in the following positions

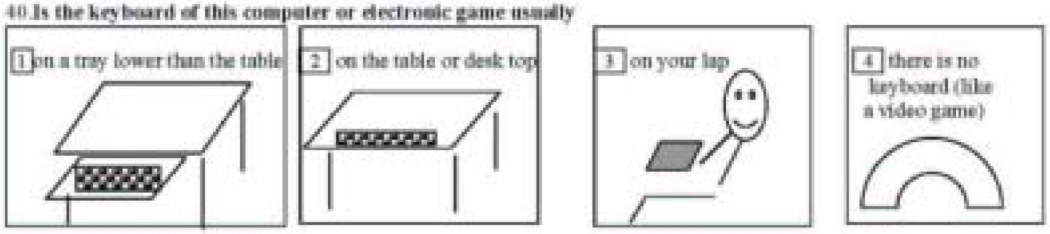
a. standing :	never	some	half the time	most of the time	all the time
b. sitting at a table or desk :	never	some	half the time	most of the time	all the time
c. sitting in a chair or couch :	never	some	half the time	most of the time	all the time
d. sitting on the floor :	never	some	half the time	most of the time	all the time
e. lying on the floor :	never	some	half the time	most of the time	all the time
f. lying on a couch or bed:	never	some	half the time	most of the time	all the time
g. other positions:	never	some	half the time	most of the time	all the time

Please mark one answer only for each of the following questions, again about the computer or game you use the most. Choose the picture that looks the closest to your computer or game.

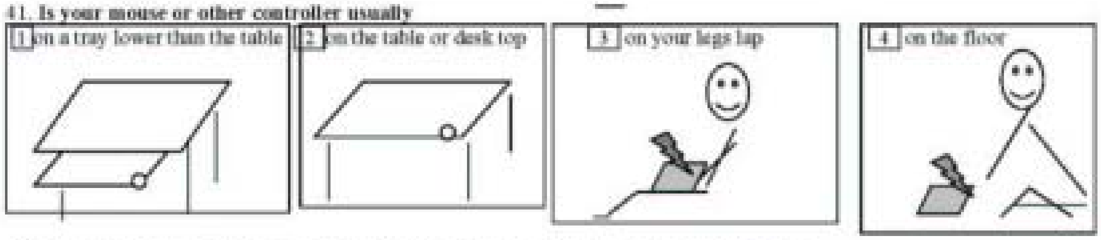
39. Is the monitor or screen of this computer or electronic game usually:



40. Is the keyboard of this computer or electronic game usually



41. Is your mouse or other controller usually



42. In the place where you normally use this computer or electronic game, is the lighting:

1 overhead (ceiling lights) 2 to the side (lamps) 3 usually daylight through a window 4 it varies

43. When you normally use this computer or electronic game, do your feet

1 easily touch the ground 2 not reach the ground 3 it varies 4 other

If OTHER, in what position are your feet? ____________________

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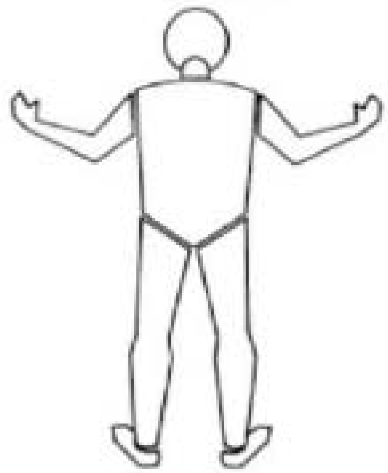
QUESTIONS ABOUT HOW YOU FEEL:

44. Please mark on this figure any part of your body where you have experienced pain, ache or discomfort in the past month. (Note to girls: please don't include pain related to your menstrual cycle.)



45. Part of body	How much pain, ache or discomfort did you have there?					How often did you have pain, ache or discomfort there?				
Head	none [n]	slight [s]	medium [m]	bad [b]	as bad as possible [w]	Never [n]	1-3 times [s]	Every week [m]	Twice a week [b]	Every day [w]
Eyes	none [n]	slight [s]	medium [m]	bad [b]	as bad as possible [w]	Never [n]	1-3 times [s]	Every week [m]	Twice a week [b]	Every day [w]
Neck or upper back	none [n]	slight [s]	medium [m]	bad [b]	as bad as possible [w]	Never [n]	1-3 times [s]	Every week [m]	Twice a week [b]	Every day [w]
Shoulder, arm or elbow	none [n]	slight [s]	medium [m]	bad [b]	as bad as possible [w]	Never [n]	1-3 times [s]	Every week [m]	Twice a week [b]	Every day [w]
Wrist or hand	none [n]	slight [s]	medium [m]	bad [b]	as bad as possible [w]	Never [n]	1-3 times [s]	Every week [m]	Twice a week [b]	Every day [w]
Stomach	none [n]	slight [s]	medium [m]	bad [b]	as bad as possible [w]	Never [n]	1-3 times [s]	Every week [m]	Twice a week [b]	Every day [w]
Lower back	none [n]	slight [s]	medium [m]	bad [b]	as bad as possible [w]	Never [n]	1-3 times [s]	Every week [m]	Twice a week [b]	Every day [w]
Hips, legs, feet	none [n]	slight [s]	medium [m]	bad [b]	as bad as possible [w]	Never [n]	1-3 times [s]	Every week [m]	Twice a week [b]	Every day [w]

46. Do you know what activity or event caused your pain, ache or discomfort? Check yes or no for each body area, and write what cause the problem:

Area	Check	If yes, what activity or event caused pain there?
Head	[y] Yes [n] No	
Eyes	[y] Yes [n] No	
Neck or upper back	[y] Yes [n] No	
Shoulder, arm, elbow	[y] Yes [n] No	
Wrist or hand	[y] Yes [n] No	
Lower back	[y] Yes [n] No	
Hips, legs, feet	[y] Yes [n] No	

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47. If you did have pain , ache or discomfort in the past month, did you do anything or change what you do in your daily life because of it? Circle: Yes No
Yes No

48.If you said yes, please check all the changes you made:
a. ____ saw doctor or nurse
b. ____ missed school
c. ____ took medicine (including aspirin, Tylenol etc.)
d ____ stopped using computer or used less
e.____ stopped electronic games or used less
f. ____ stopped exercise or other activity, or did less
g.____ other: what did you do? ______________________________
If you saw a doctor or nurse, what did she or he say the problem was?
____

49. Do your eyes get blurry or have other problems when you	
a. use a computer	Yes No
b. use a hand-held video game	Yes No
c. use a TV-based video game	Yes No
d. watch TV	Yes No
e. read	Yes No

If you answered yes, please describe the problem(s): ______________________________
____

50. In the past year did you visit the doctor for any reason other than a routine check-up? Yes No
If you answered yes, what did you see a doctor for?
____
____

General Information

Are you [1] Right handed [2] Left handed [3] Use both	Height ____ feet ____ inches Weight ______ pounds
[g] girl [b] boy	When were you born? Month ______ Year ______
Do you consider yourself (check all that apply): [W] White [B] Black or African American [H] Hispanic or Latino [A] Asian [I] American Indian/Alaska Native [O] Other: ______________	
Do you wear glasses or contact lenses? Yes No	Today's date:

Do you have any comments about computer and electronic game use, or about this survey? Please write them here:
____
____
____
____

Thanks for your help and time!

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Appendix B:

Survey testing

The survey was tested in three phases. In the first instrument feasibility test, a convenience sample was asked to complete and return a survey mailed to them, two months in a row. In the second phase, following modification of the survey, subjects were also tested twice and observed at their computers as they filled out the survey. In the final pilot study, designed to assess instrument reliability, parental consent was obtained to carry out the survey with children in the classroom.

At each stage of development the survey was distributed to ergonomists, physical activity researchers and epidemiologists to provide comments about the design, question content and format and layout. (Reviewers' names and affiliations at the time are listed at the end of this section.) Their comments were incorporated as much as possible.

(1) Field tests

The initial survey was five pages long, consisting of 27 questions, several with multiple sections. The reading level was about sixth grade on the Flesch Kincaid scale. The survey asked respondents to indicate the number of minutes spent in the past week on various activities, measure the dimensions of their normal computer workstation and mark on a body map where they experienced pain symptoms in the past month that lasted more than one day or occurred more than once a week. It was mailed twice to a convenience sample of ten children known to the researcher, aged six to seventeen. Consent forms were filled out by parents and by children. Although the survey was not difficult for older children to fill out, or for younger children with their parents, the questions about measuring the computer workstation were almost uniformly ignored, indicating that this format was onerous. Few respondents managed to fill out two surveys. Following analysis of this survey distribution process, consideration of the ages of respondents and additional feedback from experts, the survey was revised.

The second format asked respondents to check categories of time frequency and duration in which various activities were normally performed, and to mark on a timeline the actual times the activities were performed on the previous day, in attempt to validate the time reporting format. The computer setup questions were changed to pictures of various postures which respondents were asked to check as most similar to their own typical posture. The body map of question was expanded, asking about symptoms experienced in the past month and yesterday. This was administered twice to a convenience sample of 10, aged 12-18, in the presence of the researcher. To validate the posture reporting questions, the researcher observed the subject during administration of the survey and filled out the posture questions. Subjects were also debriefed following the survey by their opinions about the survey difficulty, relevance of questions, language and general interest.

Because of the small sample size and many empty cells, it was not possible to properly evaluate test-retest reliability following the survey. On a qualitative level, there was little or no correlation between observed postures and postures reported by subjects. Self-report of computer use postures, particularly by younger subjects, requires in-depth evaluation before it can be considered an adequate method for assessing exposure. The subjects reported that the survey was easy to fill out, and somewhat interesting. The language was not perceived as difficult by anyone, including the youngest subject who is not a native English speaker. Almost without fail, subjects criticized the items about time spent yesterday in various activities, finding them repetitive and confusing. Several subjects offered recommendations for improving the language to make it more up-to-date and understandable. These observations and input were used to produce the draft used in the pilot study.

(2) Pilot study

The Computer Use And Symptoms Survey used in the pilot study consisted of 155 questions. Thirty-three addressed the frequency and duration of activities, 19 described the subject's usual computer workstation, 95 covered symptoms frequency, duration and impact, and 8 were demographic. Most of the exposure items consisted of 5 ordinal categories describing frequency and duration of exposure. Frequency and intensity of symptoms were addressed for 12 body areas, as were impact and potential cause, using the same categorical format with different labels.

Recruitment and consent letters were sent to 114 High School (HS) and 101 Middle School (MS) families. 60 responses were received for a 28% return rate. Twenty-nine HS families and 27 MS families returned forms on time; 17% of the HS parents and 15% of the MS parents responding refused consent. Four forms came in after the deadline. The survey was distributed to the 42 subjects who showed up on the distribution date, half in each school. Two of the middle school students declined to participate. Fourteen days later, 21 participants returned for the retest, as did two new MS subjects. Thus, single test data is available on 44 subjects and retest data on 21. All subjects completed the survey in less than 20 minutes. Few subjects asked for help in completing the survey, and when queried about how hard it was to fill out, most reported no problems.

Data were analyzed for frequency distributions, including breakdowns by age, sex and grade. Exposure and symptoms variables developed for this survey were evaluated for test-retest liability, and criterion validity for one item was established. Because of the small number of cases, tests for association between exposure and outcome variables were not carried out.

(a) *Retest reliability*

Tests and retest datasets were matched and analyzed for consistency. Computer use, symptoms and other categorical and nominal variables were evaluated using Cohen’s kappa (SPSS), weighted kappa (Analyse-it Excel add-in , 2001) and the intraclass correlation coefficient (SPSS). Continuous variables were evaluated using the intraclass correlation coefficient.

The Cohen's kappa procedure corrects reliability measures for chance agreement. The weighted kappa weights the score for the distance between values, and is thus appropriate for ordinal categories. SPSS and the Analyse-it program use unit weights, whereas the quadratic weighting is considered more informative for tables with sparse data. SPSS will not carry out the kappa analysis when not every category is selected by subjects in both test and retest. Analyse-it does allow the analysis of non-square tables by defining each variable as containing all possible values. The intraclass correlation coefficient is the mathematical equivalent to quadratic weighted kappa, and thus can be used to approximate the value.

(b) Criterion validity

Two forms of the exercise questions were asked, the newly developed exercise frequency and duration items and the format commonly used for self-reported physical activity, the Godin-Shephard Scale (Godin and Shephard, 1997), in order to establish criterion validity for the new format. Correlation was tested using the Spearman's rho coefficient. The exercise items developed for this survey were the same format as all other activity questions, that is two sections asking about monthly frequency and daily duration of physical activity. These items were converted to a continuous exercise score by multiplying the days per month by the minutes per day for each subject. The Godin-Shephard scale represents one of the gold standards of physical activity research and has been found to be moderately reliable and valid in young adolescent population (Sallis, 1993). The Godin-Shephard Scale asks about the number of times per week the subject does heavy, medium and light exercise. A single exercise variable is produced, weighting heavy, medium and light exercise by multiplying the reported normal weekly bouts by 9, 5 and 3 respectively, summing to a score which approximates the energy demand of these activities (Godin and Shephard, 1997). The non-parametric test is used here because of the small sample size and because exercise estimates are typically positively skewed (Aaron et al., 1995).

(c) Results

Virtually no responses were indicated on the body map. Thus only responses to the categorical symptoms questions were evaluated.

Symptoms reporting was similar between grades. As is found throughout the literature, boys in this sample report less than girls, with 79% reporting any symptoms compared to 100% of the girls; 40% of girls report weekly upper back or upper extremity symptoms compared to 16% of boys. These proportions are similar to those reported in the literature (Brattberg, 1994, de Inocencio, 1998, Malleson et al., 1992)

(d) Reliability

Twelve of the 20 items concerning frequency and duration of exposure to potential risk factors showed fair to good reliability: five demonstrated an ICC higher than .60, and four produced coefficients between .40 and .60, with an additional three above .3, as shown in Table 1. Frequency items showing high retest reliability included computer use at school (ICC=.74), TV based computer games and arcade games. Moderate reliability was shown for exercise (ICC=.53), reading (Y.48) and hand-held game use (Y.34). Duration items with good reliability were computer use at home on nonschool days (ICC=.79), TV based games (ICC=.9), and arcade use (ICC=.65). Moderate reliability was shown for computer use at home on schooldays (ICC=.49) and reading (ICC=.45), with computer use at school ICC=(.35) and handheld game use (ICC=.33) showing marginally acceptable reliability.

Table 1. Activity Item Reliability Scores

	ICC	Unit weighted kappa
Time on TV-based game	.90	.82
Time home—not school day	.82	.59
Often use computer at school	.74	.61
Time arcade games	.65	.55
Often TV-based game	.56	.55
Often exercise	.53	.31
Time use computer at home—school day	.49	.45
Often read	.48	.34
Time read	.45	.43
Time handheld game	.38	.3
Time use computer at school	.35	.31
Often use handheld game	.34	.48
Often use arcade games	.26	.11
Time exercise	.26	.3
Often watch TV or video	.08	.12
Time watch TV or video	.05	.09

Of the 24 symptoms items, ten items showed moderate to high retest reliability and another three were between .3 and .4. This is illustrated in table 2 below.

Table 2. Test-retest Intraclass Correlation Coefficients for Symptoms Frequency and Intensity

Area	Frequency	Intensity
Wrist – R	0.83	0.72
Eyes	0.70	0.58
Low back	0.67	0.66
Legs	0.67	0.52
Arm - L	0.65	No variance
Head	0.47	0.37
Wrist - L	0.33	0.32
Upper Back	0.26	-0.08
Shoulder - R	0.23	No variance
Neck	0.11	-0.03
Arm - R	No variance	No variance
Shoulder - L	No variance	No variance

Five items had no variance in one of the tests and could not be analyzed. The upper back and neck questions had very low coefficients, and the shoulder and arm questions could not be analyzed. For the eight true continuous variables (age at first use of the electronic devices and number of times exercising at various intensities), the ICC was high for 3 items, moderate for 2, and low to marginal for the remaining 3, as shown in table 3. The highest ICC of .81 for the number of times hard exercise takes place is consistent with the literature, as are the lower values for medium and light exercise (Sallis, 1993).

Table 3. ICCs for Age and Exercise Variables

Age first used computer at home	.83
Weekly hard exercise	.82
Age first used handheld game	.81
Weekly light exercise	.44
Weekly medium exercise	.41
Age first used computer at school	.36
Age first used arcade game	.36
Age first used TV game	.26

The unit-weighted kappas produced correspond fairly well with the ICC; typically the ICCs are slightly higher, but in some cases they are not. Using the ICC to approximate the quadratic weighted kappa does not make unreliable items any better!

(3) Criterion validity

The categorical exercise frequency and duration responses were converted to reported days per month and multiplied by reported minutes per day to provide an exercise load score. In accordance with the method developed by Godin and Shephard and validated in this age group by Sallis, the frequency responses for the three continuous exercise questions were weighted with average metabolic equivalent values and summed to produce an exercise load score. The CUSS exercise scores correlated highly with the Godin-Shepard scores (Spearman's ρ =.652, p<.01) establishing criterion validity for this form of question on exercise. The newly developed question format produces a variable that correlates well with the current standard of measurement of self-reported physical activity. Although it has not been established that children and adolescents answer similarly structured questions about other activity with the same reliability and validity, this does support the expectation that the questions as developed are reasonable tools for assessing activity.

(4) Interpretation of test-retest results

If a questionnaire item is good, subjects should say virtually the same thing about unchanging traits from time 1 to time 2, and show strong agreement for items that might change a little. What level of agreement is required depends to some extent on the attribute being tested. Cohen’s Kappa is considered moderate above .4, good above .6 and excellent above .8. ICCs used to approximate the quadratic-weighted kappa are evaluated at the same levels, and statistical significance is also considered. Adequate correlation is established with a Spearman’s role above about .30-.35.

The activity items ask for estimates of usual frequency or duration. We are assuming that the behavior being estimated is somewhat consistent over time. The literature shows a wide variation in physical activity estimates by season, and more reliable reporting when the time frame is shorter (Rifas-Shiman, et al., 2001). Some variation must be expected from day to day. However, given that the activity estimates are of typical behavior not reports of actual past activity in a specified time, extreme shifts should be rare; that is, responses should not change from "never" to "daily" in one week. Similarly, responses concerning the age at which an activity first took place should not vary much.

The answer format developed and tested here seems adequately reliable for collecting symptoms data in this population. Of the intraclass correlation coefficients for exposure and outcomes, 56% are above 0.4, showing moderate to good retest reliability. The use items with marginal reliability were also those with the least variability: four with the lowest levels of use (school computer use, both handheld game items, and arcade games frequency) and three with the highest (both television watching items and time exercising). A low ICC score probably has more to do with the lack of variation in results than with problems with the item, as questions in the virtually identical format are answered consistently.

Similarly, the kappa score for symptoms was zero in 5 and close to that in 3 variables, shown in table 4. These were the areas that showed low variability, therefore, it is likely that the low retest reliability was due to the limited range. The combined exposure variables for time and duration of physical activity as measured here correlate well with one of the few activity question formats that has been validated in subjects between 12 and 18 years of age, the Godin-Shephard activity scale. Although it has not been established that children and adolescents answer similarly structured questions about other activity with the same reliability and validity, this does support the expectation that the questions as developed are reasonable tools for assessing activity.

Table 4. Test-retest Kappas and ICCs for symptoms frequency (F) and intensity (I) variables

	Weighted kappa	ICC	p
Wrist - R (F)	0.61	0.83	<.01
Eyes (I)	0.58	0.58	<.01
Wrist - R (I)	0.55	0.72	<.01
Low Back (I)	0.55	0.66	<.01
Eyes (F)	0.52	0.7	<.01
Legs (F)	0.52	0.67	<.01
Low Back (F)	0.51	0.67	<.01
Legs (I)	0.48	0.52	<.01
Head (F)	0.35	0.47	0.02
Arm - L (F)	0.35	0.65	<.01
Upper Back (F)	0.25	0.26	NS
Head (I)	0.24	0.37	0.04
Wrist - L (I)	0.23	0.32	0.08
Wrist - L (F)	0.19	0.33	0.08
Upper Back (I)	0.11	-0.08	NS
Neck (F)	0.07	0.11	NS
Neck (I)	0.07	-0.03	NS
Shoulder – R (F)	0.022	0.23	NS
Shoulder – R (I)	0	no variance	
Shoulder – L (I)	0	no variance	
Arm - R (I)	0	no variance	
Arm - R (F)	0	no variance	
Arm - L (I)	0	no variance	

The scale could influence reliability scores. In discussing intraindividual variability and physical activity assessment, Baranowski and de Moor observe that. “Any factor that would restrict the range of the variables, e.g., ceiling effects, floor effects, will reduce the intraclass correlation…This is because the …error term would be proportionally larger in the low between-subject variability condition.” (Baranowski and de Moor, 2000). This holds true for the scales used in this pilot study, particularly in the highly detailed symptoms items. Thus, these results are probably influenced by the large number of empty cells in the database. Because of these results, and following conversations with colleagues such as Jeffrey Katz, several of the symptoms items were collapsed in the final survey.

An additional limitation is observed in the symptoms questions: Although symptoms responses should be consistent, they cannot be expected to be identical as the reporting period is different when the tests are separated in time. Thus, asking subjects about the past month two weeks apart requires them to report on two different times. However, reasonably good reliability was still established.

(5) Changes to survey

(a) Variable changes

To simplify the survey process, and develop variables with adequate variance in a large population, several items will be combined. Other researchers have found that combining upper extremity symptoms increases the validity of commonly used clinical screening tools (Beaton, et al., 2001). In the survey revision, the items for intensity and frequency of symptoms in the arm, elbow and shoulder will be combined as will neck and upper back. Subjects will not be required to report on frequency and severity of symptoms separately for the left and right sides, and the body map markings will be made on one figure rather than front and back figures. Finally, the body map was enlarged and directive text was added to encourage consistent responses.

The scale for reporting electronic device use was clearly not differentiated adequately at the higher level, leading to a notable ceiling effect. This scale has been shifted, and its interval properties improved. The scale is similar to that used by other researchers (Harris and Straker, 2000, Katz, et al., 2000). An additional question about maximum duration of single use was added.

(b) Changes to the survey distribution process

Two major practical problems limited the number of subjects and interfered with recruitment and the retest. First, access to subjects was severely limited by the requirement that all subjects be contacted only after a parent returned a consent form. The final survey was carried out with implied consent process. Parents who wished to refuse consent were asked to return letters, all others were assumed to have consented.

Second, some students with parental consent did not show up, others did not return for the retest. Unwittingly, the first middle school session was scheduled the period following the release of report cards, and this group was not entirely cooperative. Similarly, the second session was scheduled the afternoon preceding the beginning of Easter break, which probably reduced returns. The second high school session was not well organized. Reminder letters to the principals as to who was expected in the second session, and perhaps to subjects or their parents might have increased turnout. A small incentive (an ergonomic pen holder or a candy) was advertised to reward students and improve attendance.

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Appendix C

Domain	Variable content	Type	Number of variables
Activity frequency	Frequency	5 category ordinal	6
Activity duration	Longest time without break	5 category ordinal	4
Activity duration	Time spent on typical day	5 category ordinal	11
Activity duration	Age at first use	continuous	4
Equipment	Position used	5 category ordinal	6
Equipment	Location used most	4 category nominal	1
Equipment	Posture	4 category nominal	5
Equipment	Kind used most	4-6 category nominal	4
Equipment	Comfort	dichotomous	1
Symptoms occurrence	In past month	dichotomous	10
Symptoms occurrence	In eyes while using device	dichotomous	5
Symptoms intensity	None to most	5-category ordinal	8
Symptoms frequency	Never to daily	5-category ordinal	8
Symptoms cause		string	7
Symptoms impact	Changes made	dichotomous	8
Health	Doctor visits	dichotomous and string	2
Demographics	Height (ft)	continuous	1
	Height (in)	continuous	1
	Birth month	continuous	1
	Birth year	continuous	1
	Race	6 category nominal – multiple responses allowed	1
	School	5 category nominal	1
	Gender	dichotomous	1
	Weight (lbs)	continuous	1
	Vision correction	dichotomous	1
	Handedness	3 category nominal	1

Appendix D: Derived variables

Domain	Source variable	Derivation	Type	Values
High frequency activity	Activity frequency	Collapsed lowest 4 categories	dichotomous	Daily/almost daily, <=2-3 times/wk
Activity frequency level	Activity frequency	Collapsed lowest 3 categories	3 category ordinal	Daily/almost daily, 2-3 days/wk, <=weekly
Activity time in hours per day	Estimated time spent on typical day	Midpoint of category, collapsed two top and two bottom categories	3 category interval	>=3 hr, 1-2 hr, <0.5 hr
Activity duration in hours	Longest time without a break	Midpoint of category	3 category interval	>=2 hr, 0.5-1.5hr, <0.5 hr.
Days of activity per month	Activity frequency	Mid point of scale in days		28, 12, 4,2, never
Weekly computer use	Weekly activity time	Add weekly home and school computer use		
Electronic load	Weekly activity time	Add weekly computer use, TV-based game and hand-held game		
Media load	Weekly activity time	Add electronic load and TV watching		
Time tertiles	Weekly *activity*	Split weekly variables into thirds	categorical	Varies with *activity*
Years of electronic device use	Birth year and age at first use	Current age minus age at first use	continuous	Continuous

Domain	Source variable	Derivation	Type	Values
Symptoms in the neck or upper extremities	Symptoms *experienced* in the past month	Any combination of symptoms in these areas	dichotomous	
Symptoms severity	Symptoms intensity, symptoms intensity	Multiply mid point of scale in days by intensity	continuous	Continuous
Age	Birth month and year	Calculated as of 1/1/2003, missing imputed as mean of two contiguous records	continuous	Continuous
Age level	Age		interval	<14, >14-16, >16
School level	School		dichotomous	Middle school, high school
Grade level	School		interval	7-8, 9-10, 11-12
Race category	Race		dichotomous	White, nonwhite or multiple
Body mass index (BMI)	Weight, height	703*Weight/height^2	continuous	
BMI percentiles	BMI, age, gender	BMI normed for age and gender	continuous	
Risk of overweight	BMI percentile	Risk categories for BMI percentiles for age and gender	dichotomous	Not at risk of overweight, at risk of overweight
Overweight status	BMI percentile	Risk categories for BMI percentiles for age and gender	3 category nominal	Not at risk of overweight, at risk of overweight, overweight

Appendix E

Recruitment and consent letters

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