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Upper Extremity Pain and Computer Use Among Engineering Graduate Students

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Background *The objective of this study was to investigate risk factors associated with persistent or recurrent upper extremity and neck pain among engineering graduate students.*
Methods *A random sample of 206 Electrical Engineering and Computer Science (EECS) graduate students at a large public university completed an online questionnaire.*
Results *Approximately 60% of respondents reported upper extremity or neck pain attributed to computer use and reported a mean pain severity score of 4.5 (±2.2; scale 0–10). In a final logistic regression model, female gender, years of computer use, and hours of computer use per week were significantly associated with pain.*
Conclusions *The high prevalence of upper extremity pain reported by graduate students suggests a public health need to identify interventions that will reduce symptom severity and prevent impairment.* Am. J. Ind. Med. 46:297–303, 2004. © *2004 Wiley-Liss, Inc.*

KEY WORDS: musculoskeletal; pain; graduate students; computer; ergonomics

INTRODUCTION

New employees who perform computer intensive work are at risk for developing pain and musculoskeletal disorders at the wrist, forearm, and neck [Gerr et al., 2002]. Workplace risk factors include number of hours per week of computer use, working in non-neutral body postures (e.g., reaching for mouse, looking up at a computer monitor), increasing age, and being female [Punnett and Berqvist, 1997; Tittiranonda et al., 1999; Marcus et al., 2002].

With the increasing use of computers by secondary school and college students there is concern that the young may also be at increased risk for disabling musculoskeletal disorders. A survey of 1,544 graduating seniors at Harvard University, reported that over half of the students experienced symptoms with computer use, and 12.6% experienced symptoms after computing for 1 hr or less [Katz et al., 2000]. Risk factors were academic concentration in computer science, female gender, and using a computer more than 20 hr/week.

To date, no studies have estimated the prevalence of upper extremity symptoms among graduate students. In 1995, there were over 2 million graduate students enrolled in the United States [National Center for Education Statistics, 2001]. Compared to undergraduate students, graduate students may be at greater risk for musculoskeletal symptoms and disorders due to the intensive computer use required for data analysis and thesis writing, as well as employment as graduate student researchers (GSRs) and teaching assistants. The purpose of this study was to determine whether computer use was associated with an increased risk of upper extremity and neck pain among graduate students in Electrical Engineering and Computer Science (EECS) at a large public university.

METHODS

The primary hypothesis was that hours of computer use per week (20 or more hours per week), by Computer Science

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and Electrical Engineering graduate students is associated with an increased prevalence of self-reported persistent or recurrent upper extremity or neck pain. Other objectives of the study were to: (1) quantify the extent of computer use by these students; (2) determine the proportion of students who sought medical treatment for symptoms related to computer use; and (3) estimate the extent of functional limitations related to upper extremity symptoms.

The study utilized a cross-sectional design and was carried out in the spring of 2002. Data was collected via an online questionnaire or by telephone interview.

Instrument Development

The online questionnaire assessed demographics (gender, age, and year of graduate study), upper extremity and neck symptoms, and medical care. To assess functional limitations, the questionnaire included the Student Health Related Role Function (SHRRF) which was developed for undergraduate students [Katz et al., 2002]. Exposure was evaluated based on subject estimated number of years of using a computer for more than 10 hr/week and number of hours per week of computer use per year in graduate school. The questionnaire also assessed, using a list, activities (accident, computer use, laboratory work, music, sports, other) which were associated with the onset of symptoms. If the student selected computer use, they were directed to select from another list (class, thesis, graduate student instructor (GSI) duties, GSR duties, other). An open ended question assessed the interventions that most improved their upper extremity or neck condition. The content validity of the instrument was improved by consulting with a panel of medical, ergonomic, and epidemiologic experts, as well as interviews with students, health care providers, and health educators. The questionnaire was pilot tested with six graduate students prior to being administered to the study population.

Subjects and Sampling

The Human Subjects Committee at the University of California at Berkeley approved the study protocol. Three hundred four students were randomly selected from the list of all 500 registered, full-time graduate students in the Computer Science and Electrical Engineering Department in the spring of 2002. Students were invited to participate in the study via an e-mail announcement from the Department Chair. The e-mail announcement included an internet link to the online questionnaire login page. Students were required to input their student identification number to access the consent statement and the study questionnaire. Starting 2 weeks after the e-mail announcement was sent, non-responders were contacted by telephone and offered the option of completing the questionnaire by telephone interview.

Data Analysis

Non-participants were compared to the participants on gender and age using the χ^2 statistic. Summary measures of descriptive variables were calculated to characterize the study population including: year in graduate school, years of use of computers for greater than 10 hr/week, hours of computer use by year in graduate school, and medical care.

Univariate logistic regression analysis was performed on all predictor variables: age, year of study, years of computer use, and hours per week of computer use. Subjects were classified as a case based on their positive response to two questions; the first whether or not they experienced persistent or recurrent pain in the upper extremities in graduate school, and the second whether the pain was related to computer use. Initially, hours of exposure to the computer was stratified on five levels: less than 10 hr/week, 10–19 hr, 20–29 hr, and 30–39 hr, and 40 or more hours. The less than 10 hr/week group was combined with the 10–19 hr/week group to make the group sizes comparable. Significant variables ($P < 0.1$) were included into a full logistic regression model. A second model examined the association to cases with just pain in the finger/hand/wrist region.

RESULTS

Population

Of the 304 graduate students randomly selected, 206 completed the questionnaire (67% participation rate) with 69% completing the questionnaire online, and 31% by telephone. Figure 1 is a diagram of the recruitment rates and rates of responses to key questions. The 98 non-participants were not significantly different in gender or age distribution from the participants (Table I). The respondents by year of graduate study were: year 1, 54 (26%); year 2, 36 (17%); year 3, 32 (16%); year 4, 33 (16%); year 5, 26 (13%); and 25 (12%) were beyond the fifth year of study.

Computer usage prior to graduate school was common and computer usage steadily increased from year to year in graduate school. More than half of participants reported using the computer for more than 10 hr/week for 8 or more years. The computer use pattern (hours per week) by year of graduate study is summarized in Figure 2. Participants responded for their current year of study and all prior years. The most common pattern, reported across all years, was to use a computer for greater than 40 hr/week. The percent reporting greater than 40 hr/week increased each year in graduate school, beginning with 34% of participants in the first year and increasing to 56% in the highest years of study.

The possibility of recall bias among students in their later years of graduate training (e.g., underestimating computer usage in their first year) was investigated by examining the mean number of hours of computer use per week for the

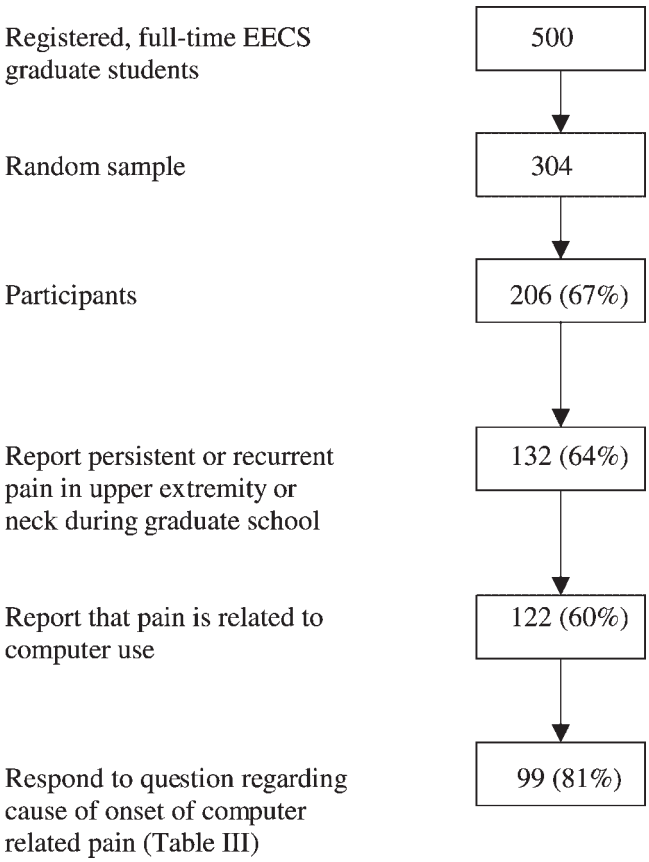

FIGURE 1. Schematic flow diagram of recruitment rates and rates of responses to key questions.

first year of graduate school as reported by students based on their current year in graduate school. The mean values are year 1 students, 31 hr/week; year 2, 34; year 3, 31; year 4, 31; year 5, 35; and year 6, 26. Based on these data there is no apparent recall bias.

Prevalence of Pain

Of all participants, 64% (132/206) reported experiencing persistent or recurrent pain in any upper extremity or neck region during graduate school (Table II). Seven percent of these reported that their pain was caused by a sports injury or a non-school related event. The prevalence of pain was highest in the finger/hand/wrist region of the body, followed by shoulder/neck, and forearm/elbow. Most of these reported that this pain was related to computer use. Of all participants, 60% (122/206) reported persistent or recurrent upper extremity or neck pain related to computer use.

Students were asked when they first noticed computer related pain; 41% reported onset prior to starting graduate school. For the others, the onset of pain was similarly distributed over the first 3 years (approximately 20% per year) then declined. Of the 122 with computer related pain, 99 responded to a question identifying the cause their computer related pain (Table III). The activity most often attributed to the onset of symptoms was work related to GSR duties. Few attributed the onset of symptoms to writing their thesis, working in a laboratory, playing a musical instrument, or sports.

The mean pain level of those reporting computer-related pain in the upper extremities or neck was 4.5 (SD 2.2) (scale 0–10 with 0 = none and 10 = unbearable). By body region, the mean pain score was highest for those with forearm/elbow (pain 5.2, SD 2.4; N = 34), followed by shoulder/neck (pain 4.6, SD 2.1; N = 48) followed by finger/hand/wrist (pain 4.4, SD 2.2; N = 99).

TABLE I. Comparison of Demographic Characteristics of Participants and Non-Participants by Gender and Age

	Participants (N = 206)	Non-participants (N = 94)[a]	*P* value*
Gender (male)	85% (176)	84% (79)	0.75
Age: 21–25	49% (101)	47% (44)	0.66
Age: 26–30	40% (82)	38% (36)	
Age: 31+	11% (23)	15% (14)	

[a]Demographic information was unavailable for four non-participants.
*χ^2 statistic.

Physician Diagnosed Disorders

Of the 60% of respondents who reported persistent or recurrent upper extremity or neck pain related to computer use, 34% (N = 41) saw a medical care provider for the problem. The most common diagnoses were tendonitis (N = 20), repetitive strain injury (N = 16), and carpal tunnel syndrome (N = 9).

Functional Impairment

Of those with computer related pain, 61% reported some degree of functional impairment on the SHRRF scale (Table IV). On the 100 point scale, the mean functional impairment score was 6.7 (SD 8.4). The most prevalent impairment was for use of the mouse repeatedly (53%) followed by typing 10 pages on the computer (40%). Functional impairment scores of Harvard undergraduate students [Katz et al., 2002] are reported for comparison in the last two columns of Table IV.

Factors That Improved Condition

Students reported the following on the status of their condition at the time of completing the questionnaire: worsening 8%, same 61%, improving 23%, and fully

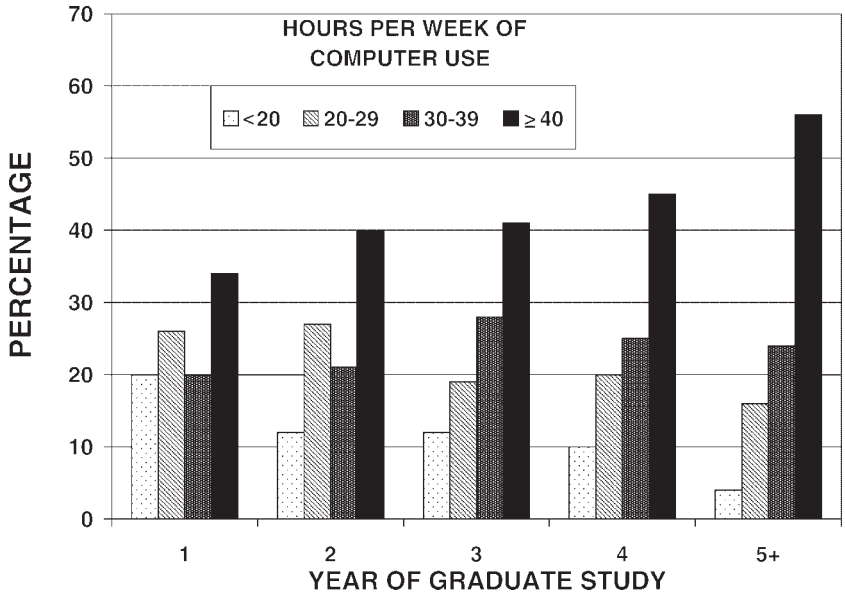

FIGURE 2. Prevalence of computer use by year of graduate study (N = 206). Computer use reported for current and earlier years.

recovered 8%. At the end of the survey, 107 students with computer related upper extremity pain completed the following open ended question, ''What has helped the most to improve your condition?'' Responses were grouped into related categories. The five most common responses were: taking a break (20%), adjusting the workstation (17%), using an ergonomic keyboard or new keyboard (17%), and adopting a better posture (12%). Only 3% listed medical treatment and only 4% listed using the computer fewer hours. As can be seen in Figure 3, there is no difference in reported computer hours by graduate year for those with computer related pain in comparison to all participants.

Univariate Analysis

Univariate logistic regression was performed on all predictor variables with case defined as participants with persistent or recurrent computer related upper extremity or neck pain. The variables age, year of study, and years of computer use were dichotomized at a level near the midpoint of their frequency distributions. Hours of computer use was grouped into four levels (<20, 20–29, 30–39, and 40 hr/week) which formed similar group sizes; less than 20 hr/week was used as the reference group. Computer use greater than or equal to 20 hr/week, female gender, and 8 or more years of use of using the computer for greater than 10 hr/week are independent factors associated with computer related pain ($P < 0.05$) and were included in the full model. Age and year of study were not significant factors ($P = 0.82$ and $P = 0.13$, respectively).

TABLE II. Prevalence of Persistent or Recurrent Upper Extremity or Neck Pain Among Graduate Students due to all Causes (N = 206)

	Due to all causes	Related to computer use
Finger/hand/wrist	53% (109)	49% (101)
Forearm/elbow	21% (44)	17% (36)
Shoulder/neck	35% (72)	26% (54)
Pain in one or more regions	64% (132)	60% (122)

TABLE III. Attributed Cause of Onset of Pain for Those Experiencing Upper Extremity or Neck Pain With Computer Use (N = 99)

	(N = 99)
Accident	0% (0)
Laboratory	2% (2)
Music	2% (2)
Sports	2% (2)
Other	5% (5)
Computer activity	88% (88)
Type of computer activity	(N = 88)
Thesis	3% (3)
Graduate student instructor (GSI)	6% (5)
Class	11% (10)
Other/do not know	34% (30)
Graduate student researcher (GSR)	47% (41)

TABLE IV. Functional Impairment Scores of Those With Computer-Related Pain Using the Student Health Related Role Function (SHRRF) Scale (N = 122)

	Missing	Mean[a]	Range	% > 0	Harvard[b], mean	Harvard[b], % > 0
1. Type 10 pages (double spaced) on the computer	3	0.51	0–4	40	0.52	36
2. Complete assignment on the computer (such as typed papers) on time	0	0.25	0–3	20	0.18	13
3. Do assignments on the computer as well as you would like	2	0.32	0–3	26	0.18	13
4. Complete handwritten assignments such as problem sets	14	0.12	0–2	11	0.32	22
5. Correspond as often as you would like by e-mail with friends, faculty, etc.	1	0.17	0–2	15	0.17	13
6. Take notes in class by hand	12	0.15	0–3	12	0.42	29
7. Take timed written examinations	14	0.08	0–2	6	0.56	33
8. Do extracurricular activities such as sports, musical instruments, hobbies	5	0.24	0–3	18	0.28	18
9. Use the mouse (or other computer pointing device) repeatedly	4	0.67	0–3	53	0.19	16
10. Carry your books around campus	6	0.16	0–3	10	0.12	15
11. Holding a book while reading[c]	4	0.19	0–2	15	—	—
SHRRF scale		6.7/100[d]	0–32.5/100[d]	61	7.8/100[d]	54

[a]Based on five point scale from 0 to 4 with verbal anchors at each point [e.g., 0, no difficulty; 4, so difficult cannot do at all].
[b]Study of Harvard undergraduate students [Katz et al., 2002].
[c]Not part of the original Harvard SHRRF scale.
[d]Sum of scores for questions 1–10 but scaled up so that denominator is 100 instead of 40.

Logistic Regresson Model of Computer-Related Pain

In the full logistic regression model of persistent or recurrent computer-related upper extremity and neck pain (Table V), all included predictors were significant ($P < 0.05$). The likelihood ratio of the final model was 0.0002.

The logistic regression process was repeated for cases being just those with computer-related finger/hand/wrist pain (N = 104). The factors that were significant in the univariate analysis were the same. In the full model, the odds ratios were similar for each of the factors except for ''years of computer use >10 hr is 8 or greater.'' For that factor the odds ratio increased to 3.6 (95% CI, 1.9–6.8).

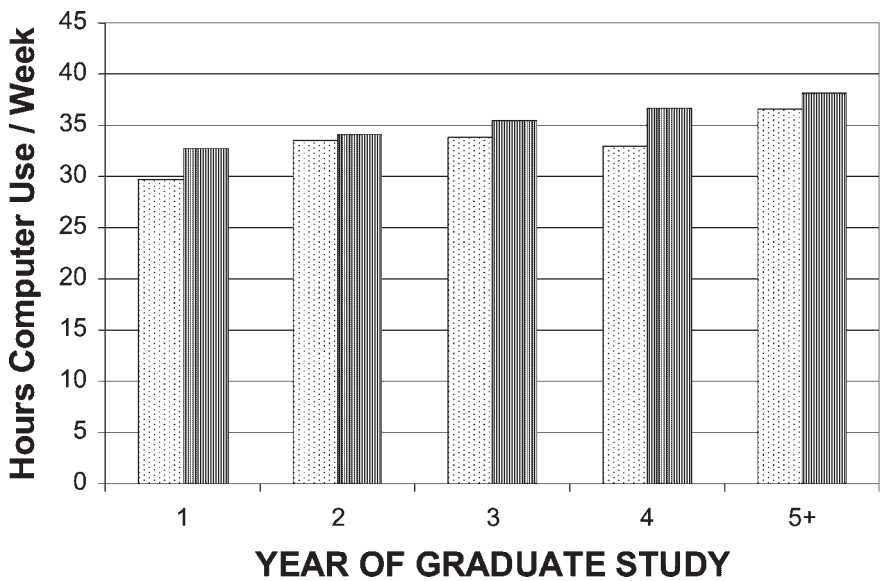

FIGURE 3. Mean hours of computer use per week by graduate year for participants without computer related upper extremity and neck pain (**first column**, N = 84) in comparison to participants with computer related upper extremity and neck pain (**second darker column**, N = 122).

TABLE V. Full Logistic Regression Model With Cases (122) Being Those With Persistent or Recurrent Computer-Related Upper Extremity or Neck Pain in Comparison to Controls (84)

	Odds ratios	95% confidence limits
Gender (female)	4.28	1.55–11.82
Years of computer use >10 hr/week is 8 or greater	2.30	1.24–4.26
Computer use 20–29 hr/week	4.32	1.29–14.48
Computer use 30–39 hr/week	6.56	1.89–22.75
Computer use 40 hr/week	3.76	1.17–12.06

DISCUSSION

This is the first study to examine patterns of computer use and associated upper extremity and neck symptoms among graduate students. EECS graduate students at a large public university report steadily increasing hours of computer use throughout graduate school. During the first year, 80% used a computer more than 20 hr/week and by the fifth year this had increased to 95%. Those reporting greater than 40 hr of computer use per week increased each year in graduate school, beginning with 34% of participants in the first year and increasing to 56% in the final years of study. In the workplace, objective exposure measures (e.g., observer, keystroke logger) document that worker estimates of hours of computer use are approximately twice actual exposure duration. However, subject estimates are proportional to actual exposure so these differences do not alter the risk estimates [Faucett and Rempel, 1996]. The reporting accuracy of students is unknown.

The prevalence of persistent or recurrent upper extremity or neck pain associated with computer use among EECS students was 60% and the mean pain severity was 4.5 on a 0–10 scale. These findings are not directly comparable to other studies due to differences in how questions are asked. Approximately 53% of senior undergraduate students reported upper extremity symptoms with computer use, but the question did not include ''persistent or recurrent'' and students did not rate their pain severity [Katz et al., 2000]. The pain prevalence is similar to studies of computer users in the workplace. Bergqvist et al. [1995] found that 62% of computer users reported neck/shoulder discomfort in the past year and a 30% prevalence of hand/arm discomfort. Bernard et al. [1994] reported prevalence rates of 17% for the shoulder and 22% for the hand/wrist. In a study of newly hired computer users, Gerr et al. [2002] reported prevalence of shoulder/neck pain in the past week (with pain more than 5 on scale of 0–10) of 10%, and 4% for hand/arm. Using the same pain threshold criteria as Gerr et al. [2002] used, the prevalence of upper extremity and neck pain among the graduate students in this study is 17%. The Gerr study went on to follow subjects prospectively with daily pain diaries and reported an annual incidence for shoulder/neck pain of 58 cases per 100 person-years and for hand/arm 39 cases per 100 person-years.

In our study, the onset of computer-related pain, for those whose pain began in graduate school, was evenly split between the first 3 years, then declined. These findings are supported by the activities students most frequently reported as the cause of pain: work as a GSR and class work, not work on their thesis. It may be that even though computer hours increase throughout graduate school, and more time is spent in the later years on the thesis, students have greater control of computer work and break patterns when writing their thesis than when doing GSR work. However, the most striking finding was that 40% of graduate student study participants who reported pain during computer use report that their symptoms began prior to graduate school. The findings suggest that prevention efforts be targeted to the undergraduate years or the early years of graduate school and that the working conditions of GSR work be investigated.

Approximately 61% of symptomatic EECS graduate students reported some degree of functional impairment as assessed by the SHRRF scale, an instrument was specifically developed for college students [Katz et al., 2002]. Responses to individual questions on the functional assessment scale were generally similar to that reported by undergraduates except for three items: difficulty taking notes in class by hand, difficulty taking timed written examinations, and difficulty using a mouse or other pointing device repeatedly (Table IV). These differences probably reflect differences in scholarly tasks between undergraduates and graduate students. However, it should be noted that for our study the scores were assessed for just the symptomatic graduate students, while in the undergraduate study all students were assessed.

The study hypothesis, that hours of computer use per week is associated with an increased risk of persistent or recurrent upper extremity or neck pain, was confirmed. In the final logistic regression model, the three factors significantly associated with computer-related upper extremity and neck pain among EECS graduate students were female gender, 8 or more years of using a computer 10 or more hours per week, and using a computer for more than 20 hr/week (Table V). In the Harvard study, the risk among undergraduate computer science students, who used a computer for 20 hr/week or more, was also elevated (OR 2.2; 95% CI, 1.1–4.3) as was female gender (OR 1.6; 95% CI, 1.3–1.9) [Katz et al., 2002]. Workplace studies, of both cross-sectional and prospective design, consistently identify an association between increasing hours per week of computer use and increased risk of upper extremity and neck pain and musculoskeletal disorders [Bernard et al., 1994; Bergqvist et al., 1995; Punnett and Berqvist, 1997; Gerr et al., 2002]. Similarly, the finding of an increased risk for female gender is observed among computer

users in the workplace (hand/arm symptoms OR = 1.6; 95% CI, 1.0–2.5; neck/shoulder OR = 1.7; 95% CI, 1.2–2.6) [Gerr et al., 2002].

This study finds that injury rates among graduate student populations are likely to be higher than is currently reported to either student health services or the workers' compensation system. Only 35% of those with upper extremity and neck pain related to computer use sought medical treatment. Previous qualitative surveys have also found that students with computer related musculoskeletal disorders are reluctant to seek treatment, and will wait until they are disabled from an important activity of daily living before seeking care [Schlossberg, 2000; Cortes et al., 2002]. Although 35% sought medical treatment, only 3% attributed improvement to medical care. This may reflect a limitation of the common forms of medical treatment (e.g., physical therapy, splinting, etc.) to address the underlying aggravating factor of the computer work. Indeed, the interventions most frequently cited as improving pain were taking breaks from computer use, adjusting the workstation, using an ergonomic or new keyboard, and working in a better posture. Interestingly, only 4% of those with computer related pain stated that decreased computer use improved their condition. It may be that the work demands were such that very few students were actually able to decrease their total hours of computer use.

The limitations of the study relate primarily to the cross-sectional design of the study and the lack of an accompanying physical examination to verify disorders. Although the participation rate was 67%, the non-participants were comparable to the participants in age and gender. However, a non-participant bias may still exist, since those without symptoms are more likely to not have participated in the study. The impact of such a bias would be to overestimate pain prevalence. Recall bias for computer use hours is another concern; however, there is no obvious personal gain for students with symptoms to exaggerate the role of computer use. It is interesting to note the steady, year-by-year increase in computer use hours, a trend which is almost identical between those with and without computer-related pain. This finding suggests that EECS graduate student work requires high hours of computer time and there is little flexibility on this risk factor. Another limitation is the possible confounding effect of computer use prior to starting graduate school. Although 41% of participants with persistent symptoms reported that their symptoms began before graduate school, we have no information on their computer use as undergraduates.

The findings of this study suggest a need to begin to evaluate interventions to reduce the risks for developing upper extremity symptoms, disorders, and disability among engineering graduate students who use computers for more than 20 hr/week. The extent to which this is a problem among graduate students of other disciplines is likely related to hours of computer use. Interventions to consider include effective training in work-rest patterns, workstation setup, and good working postures coupled with making appropriate equipment available (e.g., adjustable chairs and work surfaces, monitor stands, and ergonomic keyboards and mouse) [NRC, 2001]. In a previous survey, students expressed interest in having access to uniform ergonomics information or direct training [Schlossberg, 2000]. Based on this study, training and ergonomic interventions should be targeted toward the early graduate school years and the undergraduate years. In addition, it may be beneficial to educate the faculty who employ GSRs to these issues.

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