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Upper extremity musculoskeletal symptoms and functional impairment associated with computer use among college students[1]

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Abstract. *Purpose:* Occupational computer use has been associated with upper extremity musculoskeletal disorders among working-age adults, but little is known about computer-related musculoskeletal problems among college students. We carried out a descriptive epidemiological study of computer use-associated symptoms, functional limitations, and medication and health care utilization in this population.
Subjects and methods: Cross-sectional survey of 240 undergraduates in the second through fourth years at a residential dormitory at a four-year college with random housing assignments.
Results: 194 students returned useable surveys (81% response rate). 42% reported upper extremity pain or discomfort when using a computer in the preceding two weeks. 41% said this pain or discomfort caused functional limitation and 9% said that these symptoms hindered academic or extracurricular performance. 23% reported taking medications for upper extremity pain related to computing (4% regularly) and 16% had seen a health care provider for computer-related symptoms. Female students, students of racial/ethnic minority groups, and students who experienced symptoms with $\leqslant 1$ hour of computer use were more likely to report symptom-related functional limitation than others.
Conclusion: College students report high rates of computer use-associated upper extremity musculoskeletal symptoms and symptom-related functional limitation. Future studies should more closely examine exposure, demographic, and ergonomic correlates of these symptoms and outcomes.

Keywords: Musculoskeletal, college, computer, functional status, health care utilization

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1. Introduction

Upper extremity musculoskeletal disorders are among the most common and costly work-related medical conditions in the United States, ranking second only to back disorders [6,29]. Workplace-based studies have found evidence of an association between certain manual upper extremity work activities (e.g. awkward posture, repetitive motion and repeated load-bearing) as well as occupational computer use and the development of musculoskeletal disorders [2]. Both clerical and newspaper workers have shown a dose-response relationship between time spent using computers and development of a variety of upper-extremity musculoskeletal symptoms including pain [3,12]. Recently, Gerr and colleagues found a 21–35% annual incidence of clinically confirmed upper extremity musculoskeletal disorders among computer-using white-collar employees at eight large firms over the first year of employment [16].

Absent from this growing body of research is attention to the impact of computer use on individuals prior to their entry into the work force. Among the approximately 14.5 million undergraduate college students in America, computer use has increased markedly over the last ten years [1]. For example, many institutions now require all new students to purchase and use a laptop computer. However, little is known about the potential adverse health consequences of long-term computer use among undergraduates.

Recently, we reported a high rate of computer-related upper extremity symptoms among students who responded to a single screening question on a graduation survey at a private US college [21]. Half of all graduating students had experienced some discomfort with computing, and one in seven said they had pain after working an hour or less on the computer. We undertook the current study to validate this finding among non-graduating students and to determine whether students who reported these symptoms also reported functional limitation, impact on academic activities, or increased health service utilization related to these symptoms.

2. Methods

2.1. Design

We performed this descriptive epidemiological study at a private, four-year college in the United States after approval by the college's student research committee and the institutional review boards of the college's student health service and the Brigham and Women's Hospital, a teaching hospital of Harvard Medical School. In the spring of 2000, we administered a cross-sectional survey to a sample of undergraduate students during dinnertime in their dormitory dining hall.

2.2. Participants

Most (97%) of the 6,600 undergraduates at the study college live on campus. After the first year, students are randomly assigned to one of twelve dormitories with an average of 360 student members. These dormitories therefore contain a representative and random sample of the undergraduate population. We administered our survey in one of the larger of these dormitories (425 students in the 2nd–4th years) on two consecutive evenings. A member of the research team asked every person entering the dining hall to independently complete the survey. Based on sample size calculations for finding clinically relevant differences in functional impairment, we printed and distributed 250 copies. Students provided written consent to participate in the research study and were given ten $0.33 stamps for completing the survey.

2.3. Data elements

The purpose of this study was to determine the prevalence of symptoms and their associated functional consequences, not to determine dose-response relationships between computer exposure and outcomes. Therefore, the survey assessed the presence, timing of onset, and location of upper extremity musculoskeletal symptoms associated with computer use, the functional consequences of affected students' upper extremity pain or discomfort, and the use of medications and health services due to these symptoms. Two questions explicitly related symptoms to computer use (which included both keyboard and mouse use): "Have you experienced pain/discomfort in your hands, wrists, arms, shoulders, or neck during or after working on a computer?" and "In the past TWO WEEKS, have you experienced pain/discomfort, numbness, tingling, or other pain/discomfort in your hands, wrists, arms, shoulders, or neck when you use a computer?" In response to the second question, students who experienced symptoms could specify the average time interval between commencement of computer use and onset of symptoms (i.e., with more than one hour of computer use or with an hour or less of use).

Consequence measures included functional limitations attributed by students to their computer use-associate upper extremity symptoms and the impact of these symptoms on students' academic and extracurricular activities. Lacking validated instruments for college-age respondents on these topics, we used self-reported measures of upper-extremity pain and functional limitation which were previously described and shown to provide valid, reliable, and highly responsive means of assessing the severity of musculoskeletal disorders among non-college, working-age respondents [22,24]. Upper extremity symptom severity and functional impairment were measured with two instruments (the Brigham Symptom Severity Scale and Brigham Functional Status Scale) developed for studies of carpal tunnel syndrome [22,26]. The Symptom Severity Scale includes 11 Likert-style questions concerning day and nighttime pain, numbness, weakness, paresthesia, and fine motor skills. The Functional Status Scale has 12 Likert-style questions addressing writing, bathing and dressing, household and kitchen chores, driving, vigorous activities, and sleeping.

We also developed a student-specific functional impairment scale through focus groups and cognitive interviews with college seniors with and without upper extremity pain syndromes who graduated the year prior to the present survey [21]. This scale asked about difficulty with items such as typing a 10-page paper, taking timed written exams or notes by hand in class, or completing handwritten assignments. We called this domain "student functional impairment" and found it to be reliable, with a Cronbach's alpha of 0.86 in this development cohort. Additionally we developed an "academic/work impact" index based in part on results of the student focus groups. In this index, students were asked whether they had changed their undergraduate major, postponed deadlines, relied on other students for class notes, written papers by hand rather than type them, had another person type assignments for them, or used services provided by the college's Office for Students with Disabilities.

The survey asked about overall health status and mental health status (using the Mental Health Inventory 5-question scale (MHI-5)) in the preceding two weeks [4]. It also included detailed questions on computer type and workstation layout, computing habits, and attitudes regarding ergonomic training that will be reported in a separate paper.

2.4. Statistical analysis

To facilitate interpretation of survey results, students were categorized into one of three groups on the basis of reported of upper extremity pain or discomfort with computing: students with no symptoms, those with symptoms after more than 1 hour of computing, and those with symptoms after one hour or less computing [21]. For the Brigham Symptom Severity, Brigham Functional Status, and student-derived functional limitation and academic impairment measures, we report whether students reported any symptoms, limitation or impairment versus none.

We present descriptive statistics for demographic data and outcome measures. We used the chi-square and Fisher's Exact tests to measure the statistical significance of associations between categorical variables and the Wilcoxon Rank Sum or Kruskal Wallis test for continuous variables with non-normal distributions. Differences in MHI-5 mental health scores between groups were tested with Student's t-test and ANOVA since this variable was normally distributed. We considered an alpha of < 0.05 to indicate statistical significance and report only two-tailed p values. All descriptive and analytic statistics were computed using the SAS statistical software package (SAS Institute, Cary, NC, 1999).

3. Results

The overall response rate was 81%. 204 of 250 students returned surveys but ten participants were excluded because they did not live in the study dormitory, leaving194 useable surveys. Respondents were representative of the college student population as a whole: 88 (46%) were female, 64 (33%) self-reported as members of minority groups, 91% were US citizens, and 22% were science majors (communication from college registrar's office). Students were equally divided among sophomores, juniors, and seniors. 48% of students rated their overall health as excellent, 34% as very good, and 18% as good, fair, or poor, similar to proportions found on periodic screening of the student population as a whole (communication from college health service).

3.1. Symptom prevalence

Two thirds (67%) of all students had experienced pain or discomfort in the neck, shoulders, arms, wrists, or fingers during or after working on a computer at some time in the past. 42% of students had experienced upper extremity pain or discomfort while using a computer in the two weeks preceding the survey (Table 1). Twenty

Table 1
Prevalence and demographic distribution of computer use-associated symptoms, functional limitation and academic/work impact, mental health scores, and medication use and health services utilization

	Overall sample	Gender (%)[a]		Racial/ethnic minority (%)[a]	
	(%) ($n = 194$)	Female ($n = 88$)	Male ($n = 105$)	Yes ($n = 64$)	No ($n = 104$)
Current upper extremity pain with computing (in the past two weeks)	42	46	38	52*	37
– with $>$ 1 hour computing	31	34	29	33	31
– with $\leqslant$ 1 hour computing	10	11	10	19***	6
Symptom Severity Score > 0	59	64	55	66	55
Upper Extremity Functional Limitation Score $>$ 0	41	48	36	52**	35
Student Functional Limitation Score $>$ 0	55	66**	47	59	51
Academic Impact Score $>$ 0	9	11	7	13	8
MHI-5 Score (Mean (SD))	65.7 (21.7)	62.9 (21.3)	68.0 (21.8)	60.7 (21.6)	67.2 (22.2)
Medication use for computer use-associated pain/discomfort	23	36***	13	21	23
Health services utilization for computer use-associated pain/discomfort	16	19	12	16	13

*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.
[a]Missing data: Gender = 1, Race/Ethnicity = 26.

students (10%) reported experiencing these symptoms after using a computer for one hour or less. Female students were more likely than male students to report any adverse symptoms with computer use, but this result was not statistically significant (46% vs.38%, $p = 0.3$). Students of racial/ethnic minority groups were more likely than non-minority students to report any upper extremity symptoms with computing (52% vs. 37%, $p = 0.06$) and were significantly more likely to report symptoms after using a computer for one hour or less (19% vs. 5%, $p = 0.009$). Symptoms were unrelated to college major (science vs. non-science, data not shown).

3.2. Symptom location

Table 2 shows the location of pain or discomfort experienced by students. Significantly more female students reported experiencing pain in the neck (70% vs. 44%, $p < 0.001$) and shoulder (52% vs. 29%, $p = 0.001$) than male students. In contrast, minority students were more likely than non-minority students to report pain in the elbow (22% vs. 8%, $p = 0.02$) and forearm (47% vs. 29%, $p = 0.03$). This finding prompted a subgroup analysis of the 32 female minority students in the sample, who were significantly more likely to report pain at proximal (shoulder and neck), mid-arm (elbow), and distal (finger, hand, and wrist) upper extremity sites than other students.

3.3. Function and impact

Eighty students (41%) reported at least one functional limitation on the Brigham Function Scale and 104 (55%) reported at least one limitation related to upper extremity musculoskeletal discomfort on the student functional limitation scale (Table 1). Female students were significantly more likely than male students to report limitation in typical student activities (66% vs. 47% reporting some limitation, $p = 0.01$) and were somewhat more likely to report limitation on the Brigham Function Scale (48% of women vs. 36% of men reporting some limitation, $p =$ NS). Students of racial/ethnic minority groups were significantly more likely than non-minority students to report functional limitation on the Brigham scale (52% vs. 35%, $p = 0.04$) and were somewhat more likely to report limitations on the student-specific scale (59% vs. 51%, $p =$ NS). Seventeen students (9%) said that their upper extremity symptoms had hindered their academic or extracurricular performance as measured by a positive response to one of the academic/work impact questions. Students who reported no upper extremity pain or discomfort with computer use in the two weeks preceding the survey had significantly lower (less) functional limitation scores for both the Brigham and student-specific scales than did students who reported any symptoms with computer use (data not shown).

3.4. Mental health

The mean MHI-5 score was 65.7 (median 70) with a standard deviation of 21.7. The minimum score was

Table 2
Location of computer-associated discomfort/pain

Site of pain	Overall prevalence (%)	Proportion of female and male students reporting discomfort/pain in this location (%)[a]		Proportion of minority and non-minority students reporting discomfort/pain in this location (%)[a]		Proportion of female minority students reporting discomfort/pain in this location (%)[a]	
		Female ($n = 88$)	Male ($n = 105$)	Minority ($n = 64$)	Non-minority ($n = 110$)	Female minority ($n = 32$)	Other[b] ($n = 134$)
Neck	56	71****	44	61	52	75***	43
Shoulder	39	52***	29	39	38	56**	28
Upper arm	11	16*	8	11	10	16	7
Elbow	15	16	14	22**	8	25**	9
Forearm	37	38	37	47*	29	50*	27
Wrist	64	70	58	70	59	81**	49
Hand	40	46	35	48	33	56**	29
Fingers	29	32	26	40	23	47**	20

*$p < 0.10$, **$p < 0.05$, ***$p < 0.01$, ****$p < 0.001$ by Fisher's Exact Test.
[a]Missing data: Gender = 1, Race/Ethnicity = 26, Gender and Race/Ethnicity = 28.
[b]Other refers to male minority and male or female non-minority students.

5; 78 students (38%) scored below the 65-point cutoff recommended as a criterion for pursuing diagnostic screening for mood disorders [14]. For comparison, comparable-aged respondents in one study from the UK had a mean score of 71 [28]. There were no significant differences in MHI-5 scores by gender or by racial/ethnic minority status. MHI-5 scores were significantly lower (worse) for students who reported any type of functional limitation or adverse academic impact from upper extremity symptoms (data not shown). Twelve of the 17 students (71%) reporting academic impact from their musculoskeletal symptoms scored lower than 65 on the MHI-5 (i.e., scored below the recommended screening cutoff value for affective disorders).

3.5. Medication and health services utilization

Forty-five students (23%) had used medications specifically for upper extremity pain or discomfort in the past. 38 of these students (84% of all medication users) took medications "hardly at all," or "only now and then." Seven (16% of all medication users and 4% of the entire sample) took pills every other day or more frequently for their upper extremity pain or discomfort. Female students comprised 70% of those taking medications for upper extremity symptoms and were three times more likely to take medicine than male students (36% vs. 13%, $p < 0.001$). All seven of the students who took medications at least every other day were female ($p = 0.003$). There was no difference in rates of medication use by minority status.

Almost one in six students (16%) had seen a health care professional specifically for upper extremity pain or discomfort. Most of these students (80%) saw a physician. Neither gender nor racial/ethnic status was significantly associated with health services utilization. Students who reported academic/work impact from their symptoms were almost 5 times more likely to have seen a healthcare provider than those with no impact (53% vs. 12%, $p < 0.0001$).

3.6. Timing of symptom onset and outcome measures

Table 3 shows the relationship between computer-related upper extremity symptoms and four outcome measures (student functional limitation, academic/work impact, medication use, and health services utilization). 85% of the 80 students reporting recent (i.e., within two weeks) upper extremity symptoms reported student functional limitation scale compared to only 33% of students with no recent symptoms ($p < 0.0001$). Additionally, students reporting symptoms after computing for an hour or less were more likely to report any student functional limitation than those who took longer to develop symptoms (95% vs. 82%, p<0.001 by Cochran-Mantel-Haenszel Chi-Square for trend). A similar trend was evident for academic impact, but these results did not attain statistical significance in categorical tests. However, when these scales were analyzed as non-dichotomized continuous variables, students reporting symptoms after an hour or less of computer use had higher (worse) scores for both student functional limitation and academic impact than those reporting symptoms after a longer interval of computer use or those reporting no symptoms ($p <$ 0.0001 by the Kruskal Wallis test).

Table 3
Relationship of computer-related symptoms to functional limitation, academic/work impact, and medication use and health services utilization for computer use-associated upper extremity pain or discomfort

	Among students with *no* current computer use-related upper extremity symptoms: (%) ($n = 110$)[a]	Among students with *any* current computer use-related upper extremity symptoms reporting: (%) ($n = 80$)	Breakdown of students with *any* computer use-related upper extremity symptoms by time of computing	
			Symptoms with > 1 hour computing ($n = 60$)[b]	Symptoms with $\leqslant 1$ hour computing ($n = 20$)[b]
Student Functional Limitation Score > 0	33	85**	82	95[a]
Academic Impact Score > 0	5	14*	13	15
Medication use for computer-related pain/discomfort	19	28	25	35
Health services utilization for computer-related pain/discomfort	12	21	22	20

*$p < 0.1$, **$p < 0.001$ by Fisher's Exact Test.
[a]$p < 0.001$ by Mantel-Haenszel Chi-Square for trend.
[b]Missing data: 4 students.

The proportion of students taking medication specifically for upper extremity pain increased from 19% for those reporting no computer-related upper extremity symptoms to 28% for those reporting any recent symptoms ($p = 0.22$). There was also evidence of more medication use specifically for upper extremity pain or discomfort among those students who reported more rapid onset of symptoms with computer use (35% for those with symptoms after an hour or less of use compared to 25% among students with symptoms after more than an hour of use) but this result did not attain statistical significance. Health service utilization specifically for upper extremity pain or discomfort exhibited a plateau phenomenon between those with no current computer use-related symptoms and those with any symptoms. 12% of students reporting no upper extremity symptoms related to computer use had seen a health care provider for upper extremity pain or discomfort (presumably for other, non-computer-related conditions) compared to 21% of students who reported experiencing computer use-related upper extremity symptoms ($p = 0.11$). Students with symptoms only after more than one hour of computing had the same rate of health services utilization as those with onset of symptoms after computer use for one hour or less (22% and 20%, respectively, $p =$ NS).

Not shown on the table, MHI-5 scores were significantly lower for students reporting symptoms after more than one hour of computing (mean $= 61.4$) or symptoms after an hour or less of computing (mean 59) compared to those with no recent upper extremity pain or discomfort with computing (mean score $= 69.5$, $p = 0.02$ by ANOVA).

4. Discussion

This study shows that a substantial proportion of college students report upper extremity musculoskeletal symptoms associated with computer use. Affected students report both adverse functional outcomes and increased health service utilization related to their symptoms compared to their peers. A small but measurable proportion of students experience adverse symptoms after a relatively brief duration of computer use. These students appear to have worse functional status and increased health resource utilization (both medication use and health care visits) than their peers. The setting for this study is important in that college students surveyed in their residence may have less potential secondary gain from over-reporting symptoms or limitations than workers surveyed at their place of work.

Three of our findings are especially notable. First, we found significant gender differences in both the location and functional impact of symptoms associated with computer use, along with non-significant gender differences in overall symptom prevalence. Several studies have shown that women have higher rates of musculoskeletal disorders in the workplace. For example, Demure found that female office workers were 2–3 times more likely than male workers to develop wrist symptoms after adjusting for work exposure [10]. Latko reported that women have more nonspecific upper extremity discomfort in the workplace than men even with equal representation in industrial roles [25]. The National Research Council concluded that women appear to suffer higher rates of repetitive strain injury generally in industry, along with higher rates of carpal

tunnel syndrome both in workplace settings and in the general population [8].

However, the results in Table 1 suggest that male and female students who experience computer use-related upper extremity symptoms develop those symptoms at similar rates after given durations of computing. This may be a reflection of male and female students' similar "occupational exposure to physical stressors" or may be related to unmeasured differences in computing habits (e.g., average hours per day computing). While multivariable adjustment for such exposure variables would help to elucidate independent predictors of symptomaticity, that was not the purpose of this study. Our results show that female students experience computer use-associated upper extremity symptoms differently than their male counterparts (in a manner similar to that found in workplace settings [7,17]), are more likely to take medications for those symptoms, and are more likely to report functional limitations when they are symptomatic. These results should be of interest to college health care and educational professionals and may influence the design of future ergonomic interventions.

Second, we found significant differences in symptom prevalence and functional impact among students of different racial/ethnic groups. Although several previous studies of workplace ergonomics have found race/ethnicity to be a significant predictor of adverse outcomes of musculoskeletal disorders, researchers have generally discounted these findings. For example, Bernard found race was significantly associated with development of any upper extremity musculoskeletal disorder among newspaper VDT workers, but stated that he did not report these results because it "was felt to be a surrogate for some other variable" [3]. Using both symptom self-report and physical exam data, Hales found non-white race was significantly associated with upper extremity musculoskeletal disorders among telecommunication workers [18]. Analyzing the 1988 Occupational Health Supplement of the National Health Interview Survey, Blanc found that while non-white race was not a predictor of development of carpal tunnel syndrome (CTS), those who already had this condition and were non-white were significantly more likely to have stopped working because of the condition: "Once given the presence of CTS, non-white race appears to be a risk factor for work disability" [5].

Although 13% of survey respondents did not report race/ethnicity, we nevertheless found significant effects of racial/ethnic minority status on the prevalence, location, and impact of computer-related upper extremity pain. As with gender, these results warrant further investigation with larger study samples to permit multivariable adjustment to determine predictors of symptomaticity and dose-response relationships for college students as a whole and for selected subgroups.

Third, students reported taking medication and seeing health care providers for their upper extremity symptoms, with rates of healthcare utilization generally paralleling increased symptom severity and functional limitation. Future studies should focus on clarifying both the types of health services sought by affected students (including complementary or alternative health care providers) and the success of these interventions in alleviating symptoms. Although students' rates of health service use are lower than those found in industry (e.g., Bernard found that one third of symptomatic VDT workers had seen a healthcare provider [3]), they represent important healthcare-seeking behaviors in an otherwise young and healthy population and may have important consequences for student health management. In particular, clinic visits by affected students offer an optimal setting for implementing ergonomic education and intervention programs.

By design, we relied on student self-report of both computing habits and outcomes [3,13]. Katz previously demonstrated that self-reported symptoms were superior to physical exam measures for measuring responsiveness to change in patients with carpal tunnel syndrome [22]. Further, Friedman found that patient symptom self-reports are better predictors of subsequent work disability than either physical exam signs or a history of prior work disability [14]. In the absence of evidence that these results would not apply to student subjects as well, we therefore felt that self-report of computing habits, symptoms, and impact had sufficient validity for the purposes of this cross-sectional study.

A limitation of the study's cross-sectional design is that it precludes drawing causal connections between exposure and outcome variables. As noted, however, the purpose of this survey was not determine independent predictors of computer use-associated symptoms but rather to better define the epidemiology of (and associations between) symptomaticity and functional limitations reported by students. Another potential limitation concerns the study participants, who are a sample of students at a single competitive academic institution in the northeastern US [27]. We are in the process of replicating this study in a college in the southwestern US to determine the generalizability of our current findings and to increase the sample size to permit development of risk models to guide preventive interven-

tions. The advantages of our chosen setting included broad racial/ethnic diversity of the student population and random assignment of students into the residential dormitory.

This study opens a window on the burden of illness of upper extremity musculoskeletal symptoms related to computer use among today's college student population. Prevention of symptoms and of progression to disability is critical to the successful management of these disorders. Several recent studies have shown that functional impairment is an important predictor of delay in return to work for musculoskeletal disorders [9,23]. Studies of ergonomic interventions such as computer workstation changes and use of rest breaks have demonstrated reduced injury and improved productivity rates for high-exposure workers [11,16,19,30]. We believe the next step in investigating computer use-associated musculoskeletal disorders among college students is to better define – through multivariable risk models and longitudinal studies – the independent predictors of computer use-associated symptomaticity, functional limitation, and academic impairment in order to better tailor ergonomic or other interventions [31]. Without effectively addressing the burden of illness revealed in this study, college students may run a higher risk of developing work-related disability before actually joining the work force.

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