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Upper Extremity Pain and Computer Use Among Engineering Graduate Students: A Replication Study

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Abstract

Background—Recent literature identified upper extremity musculoskeletal symptoms at a prevalence of >40% in college populations. The study objectives were to determine weekly computer use and the prevalence of upper extremity musculoskeletal symptoms in a graduate student population, and make comparisons with previous graduate and undergraduate cohorts.

Methods—One hundred sixty-six graduate students completed a survey on computing and musculoskeletal health. Associations between individual factors and symptom status, functional limitations, academic impact, medication use, and health services utilization were determined. Logistic regression analyses evaluated the association between symptom status and computing. Cross-study comparisons were made.

Results—More symptomatic participants experienced functional limitations than asymptomatic participants (74% vs. 32%, P <0.001) and reported medication use for computing pain (34% vs. 10%, P <0.01). More participants who experienced symptoms within an hourof computing used health services compared to those who experienced symptoms after an hour of computer use (60% vs. 12%, P <0.01). Years of computer use (OR = 1.59, 95% CI 1.05–2.40) and number of years in school where weekly computer use was more than 10 hr (OR = 1.56, 95% CI 1.04–2.35) were associated with pain within an hour of computing. Cross-study comparisons found college populations more similar than different.

Conclusion—The overall findings reinforced previous literature documenting the prevalence of upper extremity musculoskeletal symptoms in college populations, suggesting an important population for participating in public health interventions designed to support healthy computing practices and identify risk factors important to evaluate in future cohort studies.

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Keywords

replication study; computer use; college students; graduate students; musculoskeletal

INTRODUCTION

Musculoskeletal disorders continue to be a significant public health burden (National Research Council, 2001). Work-related musculoskeletal disorders accounted for one-third of lost work days in 2006 [Bureau of Labor Statistics, 2007]. Computing-related musculoskeletal symptoms and disorders are expected to play a significant role in work-related musculoskeletal health issues as more than half of American workers use a computer at work [Bureau of Labor Statistics, 2003]. A recent systematic review concluded computer use was positively associated with upper extremity musculoskeletal symptoms and several disorders [Village et al., 2005].

College students are a population known to experience computing-related upper extremity musculoskeletal symptoms [Katz et al., 2000; Hupert et al., 2004; Jenkins et al., 2007]. Forty-one percent of college students in a cross-sectional study of a private Northeastern university (NEU) reported experiencing computing-related musculoskeletal symptoms [Katz et al., 2000] with 55% being limited in at least one college activity due to pain [Hupert et al., 2004]. Similar findings were found at a second university in a different geographic region (Southeast) of the United States [Jenkins et al., 2007]. Finally, a dose response relationship in participating undergraduates was documented with symptom severity increasing as daily computing time increases [Amick et al., 2003]. Coupled with the knowledge there are 15 million college students in the United States alone [U.S. Census Bureau, 2008], these findings suggest college students should be included in epidemiological studies designed to examine computing-related upper extremity musculoskeletal symptoms and disorders and their risk factors.

Recently, Schlossberg et al. [2004] reported musculoskeletal symptoms associated with computing in graduate engineering students at a college campus in the Western United States. Graduate students represent a transitional period between education and working. Schlossberg et al. [2004] reported weekly computer use by graduate students that coincides with levels seen in a literature review that found increased computer use was associated with upper extremity musculoskeletal symptoms and disorders [Village et al., 2005]. The purpose of this study was to compare epidemiologic findings on upper extremity musculoskeletal symptoms, functional impairment and computer use in graduate engineering students at a private Southwestern University (SWU) with previous graduate and undergraduate cohorts. A survey comparable to the one reported in Hupert et al. [2004] and Jenkins et al. [2007] (designed for undergraduates) was administered, but expanded with questions pertaining to computer use among graduate students as reported in Schlossberg et al. [2004].

METHODS

Sample

In the summer of 2005, 277 graduate students from the engineering school of a private university in the southwestern United States were invited to participate. Flyers advertising the study were disseminated throughout the school a week before each of seven survey events (lunches or ice cream socials). On the morning of a survey event, the graduate student association distributed emails to every engineering graduate student. Students who agreed to participate signed a consent form and completed a 40-min survey. The Institutional Review

Boards for both the University of Texas at Houston Health Sciences Center and the SWU approved the study protocol.

Survey Instrument

Participants completed the College Computing and Health Survey, first developed in 2000 [Katz et al., 2000] but modified in this study for a graduate student population. Data collected by the survey included demographic information, computer use duration, upper extremity musculoskeletal symptoms (and severity), and student functional limitations in addition to overall health and mental health. Questions regarding medication use and healthcare utilization as a result of upper extremity pain were also included. Recent questions relevant to graduate students such as number of years in graduate school and average hours of weekly computer use by year of graduate school were added.

The presence of upper extremity musculoskeletal symptoms was determined by “yes” or “no” responses to the questions “have you ever experienced pain/discomfort in your hands, wrists, arms, shoulders or neck during or after working on a computer?” To try to pinpoint time of symptom onset, participants were asked to report the month and year when pain/discomfort in the hands, wrists, arms, shoulders or neck was first noticed. Circling 0 for “no” and 1 for “yes” for 13 upper extremity body parts guided participants in identifying symptom location. Later in the survey participants were asked “in the past 2 weeks, have you experienced pain/discomfort, numbness, tingling, or other pain/discomfort in your hands, wrists, shoulders, or neck when you use a computer?” Possible responses were “no, never”, “yes, if I use the computer for several hours at a time”, “yes, if I use the computer for an hour or so”, “yes, even if I just use the computer for a few minutes”, and “yes, with virtually all activities”. Finally, participants were asked to evaluate the level of pain currently felt in each of 13 body parts by choosing from the following responses: “I do not have this symptom”, “mild”, “moderate”, “severe”, or “very severe”.

Student functional limitations focused on the ability of students to meet student role demands given current health [Katz et al., 2002; Schmidt et al., 2002]. Participants were asked how much difficulty they had completing 13 student activities, including: completing handwritten and computing assignments, corresponding with others, using computer pointing devices, note taking, carrying school books or dining trays, and concentrating on work. Responses ranged from “no difficulty” to “so difficult I could not do at all”. In the current study, the student role functioning (SRF) scale had a Cronbach’s alpha of 0.91.

The Brigham and women’s upper extremity symptom severity scale (SS) has demonstrated reliability, validity, and clinical responsiveness [Levine et al., 1993; Katz et al., 1994, 1996] and contains 11 items concerning day and night time pain, numbness, weakness, paresthesia, and fine motor skills. Responses to the first seven items ranged from 0 (none) to 4 (very severe). The remaining four items concerned pain/discomfort in the context of specific scenarios and had responses related to frequency rather than severity. In the current study the SS had a Cronbach’s alpha of 0.82.

For both the SRF and SS scales, items were equally weighted and the scales were transformed to vary between 0 and 100 [Levine et al., 1993; Katz et al., 1994; Schmidt et al., 2002]. Higher scores indicate greater symptom severity and more college student role limitations.

An academic/work impact index was created to assess any changes students had made in: major area of concentration, future field of work, class schedule, vacation plans, sports plans or other extracurricular activities, usage of note-taking services, or visits to the student disability services office for assistance with their computer-related symptoms.

A section on weekly computer use was included where participants were asked how many years they had been in graduate school and, for each year of graduate study, to indicate typical weekly hours of computer use for that year. Weekly hours of computer use ranged from <10, 10–19, 20–29, 30–39, and >40.

Other questions in the survey collected information about overall and mental health. Students were asked to rate their overall health as excellent, very good, good, fair, or poor. The mental health questions included in the survey make up the SF-36 mental health index (MHI-5) [Ware et al., 1993]. Specifically, students were asked to what extent in the past 2 weeks they had been nervous, happy, felt calm and peaceful, felt downhearted and blue, or felt so down in the dumps that nothing could cheer them up. The responses ranged from "never" to "most of the time" and were scored following a standard protocol [Ware et al., 1993]. The recommended cut-off for pursuing diagnostic screening for mood disorders is 65 [Friedman, 1997].

Statistical Analysis

Participants were categorized according to symptoms related to computing: Asymptomatic, experiencing symptoms after an hour or more of computing or experiencing symptoms after less than an hour of computing. This categorization is consistent with two previous studies among college students that employed the same survey instrument and allowed for a direct comparison of the results [Hupert et al., 2004; Jenkins et al., 2007]. To be comparable to earlier studies, the SS scale, SRF scale, and academic impairment index were dichotomized into any symptoms, functional limitations or impairment versus no symptoms, functional limitations or impairment.

Descriptive statistics were presented for outcome measures and demographic data. To be comparable to previous work, differences in pain, functioning, limitations, academic impact, mental health, medication use, and health services were assessed by gender and racial/ethnic minority status. The χ^2 and Fisher's exact tests were used to determine the statistically significant associations between categorical variables. Differences in MHI-5 scores between groups were tested using Student's *t*-test. An alpha of ≤0.05 (two tailed) was employed.

Simple logistic regression analyses were conducted to test the association of variables reported in a similar cross-sectional survey to symptoms [Schlossberg et al., 2004]. For the present analyses, two outcomes were considered separately: Those reporting any symptoms related to computing and those reporting symptoms within an hour of computer use. The independent variables included age, race/ethnicity (minority status vs. non-minority status), gender, number of years in graduate school, number of years in graduate school where computer use was greater than 10 hr/week, time-weighted average of weekly computer use, and current weekly computer use. For the last two variables weekly hours of computer use was grouped into <20, 20–29, 30–39, and >40 to facilitate comparisons with the previous study involving engineering graduate students [Schlossberg et al., 2004]. Variables in the logistic regression analyses were considered significant if $P \leq 0.10$. If variables were found to be statistically significantly correlated above a correlation coefficient of 0.70, they were not entered into a single final multiple logistic model but kept in a simple logistic model. Each outcome was considered separately. All analyses were completed using STATA v9.2 (Stata Corp., College Station, TX).

Comparing Study Findings With Other College Studies

Key findings reported in three other studies were compared with findings reported in this study, where applicable. Specifically, the proportion experiencing upper extremity pain with computing and, among those, the proportion of participants experiencing pain with more

than an hour of computing and pain within an hour of computing was compared with the two undergraduate student populations. Differences within 10% points were considered similar findings. Additionally, the proportion of participants reporting functional limitations in the student role was compared among all of the studies. Differences within 10% points were considered similar. The three body parts where most of the pain is felt were compared with two undergraduate populations. If any of these body parts were the same as the three most prevalent body parts for the other populations, this was considered a similar finding. Student functional limitations, medication use and health services utilization by pain symptoms were compared with the undergraduate studies [Hupert et al., 2004, Jenkins et al., 2007]. If the same differences reported here were observed in the other studies and within 10% points, this was considered a similar finding. Distribution of hours of computer use by year of study was compared with the graduate student study. If the overall pattern matched the other population and the proportions were within 10% of the other study, then the findings were considered similar.

RESULTS

Of the eligible students invited to participate in this study, 166 (60%) completed the surveys. The general characteristics and health status of the study participants are presented in Table I. Respondents were mostly male (75%), half were aged 26–30 years (51%) and half identified themselves as belonging to a minority group (48%). A majority (60%) had been graduate students for 1 to 3 years. There were more who participated in a sports activity (69%) compared to playing a musical instrument (28%). A majority of students surveyed reported their overall health as very good. The mean MHI-5 (mental health) score was 10 points above the recommended cut point for mood disorders.

Prevalence of Outcome Measures

Just over half of the students reported experiencing upper extremity pain with computing 2 weeks prior to answering the survey (55%) (see Table II). Ten percent of students (n =16) reported experiencing pain with computing within an hour of computer use. Overall, 55% experienced functional limitations in completing student work. Three percent (n =5) reported that upper extremity symptoms influenced their academic performance. Twenty-three percent of participants reported using medication for computer-related pain/discomfort and 16% sought health-care services for computer-related pain/discomfort.

There were no statistically significant gender-specific differences in current upper extremity computing-related pain, symptom severity, student functional limitations, academic impact, and healthcare services utilization ($P > 0.05$). However, 37% of women participants used medication for computer-related pain/discomfort compared with only 19% of men ($P < 0.05$). This finding parallels the trend (not statistically significant) towards more severe symptoms in women. Specifically, 17% of women reported pain with less than an hour of computer use as compared with only 7% of men ($P = 0.07$).

Reports of current upper extremity computing-related pain/discomfort, symptom severity, student functional limitations, academic impact, and medication use for computing-related pain/discomfort did not differ significantly by racial/ethnic minority. However, a greater proportion of participants (22%) who described themselves as belonging to a racial/ethnic minority group sought out healthcare services compared to non-minorities (12%), although the difference was not statistically significant ($P = 0.20$).

Symptom Location

The regions with the highest prevalence of pain were the neck (62%), wrists (52%), and shoulder (50%) (see Table III). For almost every region the proportion of women reporting pain/discomfort was greater than that of men, though not statistically significant. Minority students experienced a greater prevalence of pain/discomfort in the neck, shoulder, upper arms, and elbows, though not a statistically significant difference. However, minority students reported wrist, hand, and finger pain less frequently and notably less forearm pain (22% vs. 35%, $P < 0.10$) than non-minority students. For the majority of body regions a greater proportion of female minority students reported pain/discomfort than other students, though differences by body region were notable only for the upper arm (20% vs. 8%, $P < 0.10$).

Timing of Symptom Onset and Other Health Outcome Measures

Students with any current computer-related symptoms reported significantly more student functional limitations (74% vs. 32%, $P < 0.05$), significantly more medication use (34% vs. 10%, $P < 0.05$), more healthcare services utilization (20% vs. 12%) and more academic impact (4% vs. 1%) than asymptomatic students. Among symptomatic students, those with symptoms after less than an hour of computing reported notably more functional limitations (94% vs. 70%, $P < 0.10$), significantly more healthcare services utilization (60% vs. 12%, $P < 0.05$), slightly greater academic impact (6% vs. 4%) and more medication use (44% vs. 32%) than students with symptoms after 1 hr of computer use (Table IV).

Computer use During Graduate School

Sixty-three percent of students reported using the computer more than 10 hr/week for 3 years or more. Computer use in hours/week by graduate year of study is described in Figure 1. The proportion of students using the computer for less than 20 hr/week steadily decreased by year of study; conversely, the proportion of weekly computer use of 40 hr or more steadily increased by year of study and leveled off at years 4 and 5. For every study year the proportion of weekly computer use greater than 40 hr was higher than any prior computer use time. The overall time-weighted average was 33.9 hr/week of computer use. The average number of computing hours/week (and standard deviation) by total number of years in graduate school is as follows: 1 year (n =33), 35.3 (11.6); 2 years (n =27), 29.8 (10.0); 3 years (n =39), 34.1 (11.2); 4 years (n =27), 31.7 (10.1); 5 years (n =22), 38.2 (8.5); and 6 years (n =12), 31.9 (12.6). There was only one person who reported being in graduate school for 7 and 10 years and no one reported being in graduate school for 8 and 9 years.

A set of logistic regression analyses explored the association of computer use with pain attributed to computing. There was no association found between age, gender, number of years in graduate school, number of years of computer use for more than 10 hr/week, and current weekly computer use (and its time-weighted average) with either pain outcome. Weekly hours of computer use (20–29 hr) was found to be statistically significant with the first outcome, pain attributed to computer use (OR =2.51; 95% CI 1.04–6.06). A second set of logistic regression analyses found years of computer use and number of school years where computer use was 10 or more hours per week associated with the second outcome: pain attributed to computing within an hour of beginning computer use. For both exposure variables the odds ratios were about the same (years of computer use, OR =1.59, 95% CI 1.05–2.40, $P < 0.03$; years of weekly computer use more than 10 hr, OR =1.56, 95% CI 1.04–2.35, $P < 0.05$). Because the two computer use variables significantly associated with pain with computer use are highly correlated with each other (r =0.98, $P < 0.001$) a final model including both variables (multivariable) could not be constructed for the second outcome.

Comparison Across Studies

Overall our findings are consistent with previous studies of computer use and musculoskeletal symptoms among college students (summarized in Table V). Because of the differences in survey questions between the current study and the study conducted among graduate engineering students at the Western University (WU), only graduate student computing patterns could be compared. The proportion of graduate students experiencing pain with computing (55%) is comparable to the undergraduate population at the same SWU (54%) [Jenkins et al., 2007] but the proportion of graduate students experiencing pain with computer use for less than an hour (10%) is more similar to the undergraduate population at the NEU (10%) [Hupert et al., 2004]. The proportion of students experiencing some limitations in student activities (55%) was similar to the other two undergraduate populations (SWU, 62%; NEU, 55%) and the graduate population at the WU (61%). Medication use and health services utilization for computer-related pain in this population (23% and 16%, respectively) were strikingly similar to the other two undergraduate populations (27% and 15% for SWU and 23% and 16% for NEU). Consistent with the two undergraduate populations, the neck and wrist were among the most prevalent body sites affected with computer-related discomfort/pain. However, consistent with the undergraduate population at SWU, the shoulder (50%) was among the top three body parts experiencing significantly more pain prevalence than the other body parts (SWU, 56%). In this study, students with any computer-related upper extremity symptoms were more likely to experience student functioning limitations (74%) compared with students not experiencing computing-related pain (32%), as with the two previous undergraduate studies (94% vs. 40% for SWU and 85% vs. 33% for NEU).

Regarding medication use and health services utilization, we found the same pattern of use among graduate students as with undergraduate students of the same university studied previously. Specifically, this study found students with pain associated with any computer use were more likely to use medications (34% vs. 10%; 41% vs. 10% for SWU). Furthermore, graduate students experiencing pain within an hour of computing were more likely to seek healthcare compared with participants experiencing pain after an hour of computing (60% vs. 12%), similar to that found among the undergraduates (50% vs. 18% for SWU). This pattern, replicated in graduate students at the same university, was not seen for undergraduates studied at the NEU. Consistent with the NEU but not with a previous study at the same university, female participants were more likely to use medication for their computer-related pain than male students (37% vs. 19% this study; 36% vs. 13% for NEU).

In the current study, race/ethnicity was more evenly distributed (52% minority vs. 48% non-minority) compared with the two previous studies among undergraduates (25% minority for SWU and 38% minority for NEU). We found, as with the previous study at the same university, there were no racial/ethnic group-related differences in computing-related pain, functioning, medication use, or health services utilization. More minority students in this study experienced forearm pain than non-minority students, a finding consistent with participants from the NEU where minority students reported significantly more forearm and elbow pain, in addition to computing-related pain. It must be noted that for the current study, 12 participants (almost 10% of study population) did not indicate race/ethnicity. As with the previous study at the same university, there were no differences in computing-related pain seen among female minority students compared to other students, except for being more likely to experience upper arm pain (20% vs. 8%).

Regarding computer use, basic patterns of weekly computer use by year of graduate school for the population reported here and that of WU were similar. They both experienced decreases in weekly computing hours less than 20 as students progressed in school and both experienced increases in weekly computing hours of 40 or more as students progressed in

school. It was not possible to compare adjusted models examining computer use associated with symptoms because the current study did not find all of the same variables associated with symptoms as Schlossberg et al. [2004] found. Specifically, gender was not significantly associated with either symptoms outcome, and the same classifications for current weekly computer use significantly associated with symptoms by Schlossberg et al. [2004] were not statistically significant for the current study. Instead, two highly correlated variables, years of graduate school and years of computing for >10 hr/week were found to be significantly associated with pain after computing and pain within an hour of computing. Schlossberg's final model and one of the models presented here had one variable in common: years of computing for 10 hr or more per week. The similarity between models is not unexpected as the two graduate student populations had similar distributions in computer use by year of graduate school.

DISCUSSION

There is a growing body of literature from multiple universities that has identified college students as experiencing pain related to computer use [Katz et al., 2000; Hupert et al., 2004; Schlossberg et al., 2004; Jenkins et al., 2007]. The study purpose was to evaluate the prevalence of computing-related pain and functioning due to pain and describe how they varied by sociodemographic categories. By using a questionnaire designed for undergraduate populations, we made comparisons with three other college student populations. Overall, as consistent with the other studies, more than half of students in this study experienced upper extremity pain with computing within the past 2 weeks of being surveyed. Furthermore, as with the other studies, about half of students in this study were limited in their activities (whether everyday activities or student-role related). The body sites experiencing the greatest prevalence of pain were the neck, shoulders and wrist. Females were more likely to use medications for computer-related pain/discomfort. Students with any computer-related upper extremity symptoms were more likely to experience limitations in doing student activities and use medications for their pain/discomfort. Students with computer-related upper extremity symptoms after less than an hour of computing were more likely to experience limitations in doing student activities and use health services for their pain/discomfort compared with students who experienced computing-related pain after an hour or more of computing. Regarding computer use, with increasing years of graduate school students increasingly computed 40 or more hours a week. Number of years of graduate school and number of years weekly computing for 10 or more hours was associated with pain that occurred with less than an hour of computing.

We observed gender differences, significant and non-significant, in medication use, pain and both functional and student role limitations. We found women were significantly more likely to use medication for their computer-related pain than men. We observed gender differences (though non statistically significant) in functional limitations, overall pain and body site pain that were found to be significant in the two previous studies of undergraduate populations. The gender differences were likely underestimated due to the relatively small proportion of women compared to the two previous undergraduate populations studied. In this population of graduate students, women comprised 25% of the population surveyed, whereas in the previous studies women comprised about half of the study population (45% for NEU and 65% for SWU). A smaller female population makes gender differences more difficult to detect than in the previous populations. This reasoning is supported by a recent prospective cohort study that found women were more likely to develop upper extremity musculoskeletal symptoms and disorders [Gerr et al., 2002].

The difference in gender distributions between the two study populations may explain why gender was associated with the outcome at WU but not in the current study. Women

comprised 15% of the electrical engineering and computer engineering graduate students (study population) at WU (n =30). If the current study had made the same limitation in study population, there would only be three women studying computer science and eight studying electrical engineering. Assuming women in both graduate programs in computer science/ electrical engineering had similar computer use, it likely still would have been difficult to see an effect due to gender if there was one. The importance of using similar case definitions and comparable study populations cannot be overestimated when trying to accumulate evidence for testing potential risk factor/musculoskeletal symptom outcome relationships in larger and time-intensive studies.

In addition to differences in gender distribution between the two study populations, differences in case definition might also contribute to the inability to fully compare models describing pain with computer use. Specifically, Schlossberg et al. [2004] had a case definition of pain with computer use that was based on a two-part question asking about persistent or recurrent upper extremity pain and, if present, was it related to computer use. In the present study two case definitions were created using an established College Computing and Health Survey to be comparable to that of Schlossberg et al. [2004]: (1) any upper extremity pain associated with computer use and (2) upper extremity pain associated with computer use after less than an hour of computing. Schlossberg et al. [2004] found 8 or more years of computer use more than 10 hr/week and weekly computer use for more than 20 hr to be significantly associated with persistent or recurrent computer-related upper extremity pain. However, different from the WU graduate student study, we found 20–29 hr of computer use per week, but not more, compared to less than 20 hr/week to be significantly associated with any upper extremity or neck pain with computer use. For upper extremity or neck pain accompanying less than an hour of computing (approximating persistent or recurrent pain) our findings were similar to the other WU graduate student study.

The finding that weekly computing of 20–29 hr was significantly associated with experiencing symptoms after computer use and not 30–39 or 40 or more (compared to the referent group computing less than 20 hr/week) was an interesting one. We would have expected to see, if not a dose response relationship, increases in weekly computer use significantly associated with computing-related symptoms as well. One reason may be attributed to a potential “healthy student effect”, analogous to a healthy worker effect, where students who were able to continue their academic interests and transition to a computing intensive (weekly computing 30 hr or more) graduate engineering program and continue that program through a couple of years are predisposed to musculoskeletal health. Another reason could be the students who report weekly computing of 40 hr or more and are not experiencing more symptoms are adopting behaviors that promote musculoskeletal health when computing. Exploratory analyses revealed a majority of ergonomic changes towards healthy computing were accounted for by students who reported computing 30 hr or more per week. Specifically, students who reported computing 30 or more hours a week (approximately 50%) account for at least 60% of external, separate keyboard use with laptop, buying/borrowing a desk, and acquiring a more comfortable mouse. Furthermore, they account for 65% who bought/borrowed a keyboard tray, 69% who bought a more comfortable computer keyboard, and 76% who bought or borrowed a splint for wrist rest. Although this provides a plausible reason for why frequent computer users may not experience a disproportionate amount of symptoms compared to the reference group, it cannot be confirmed in a cross-sectional study. Research completed on a cohort of students who completed the same baseline questionnaire and followed throughout the semester might be able to shed some insight on this hypothesis.

The present study reported a higher prevalence of musculoskeletal symptoms than other previous studies [IJmkers et al., 2007], which might result from the differences in case definition and study cohort. Among a study population of 3, 475 office workers (mean age =42) where a case was defined as experiencing symptoms for more than 7 days in the past year, a prevalence of 44% for neck pain and 26% for hand-wrist symptoms was reported [Jensen, 2003]. The prevalence for neck pain (62%) and hand/wrist pain (>35%) is lower than that reported in the current study likely because the current study asked about any level of pain felt in the past 2 weeks, rather than pain lasting more than 7 days. In a study of U.S. office workers who work at least 15 hr/week computing where cases were defined as having experienced symptoms on a visual analog scale of 6 or above within the previous 7 days, the symptoms prevalence was 10% for neck/shoulder and 4% for hand/arm [Gerr et al., 2002]. The current study reports a much higher prevalence for these body regions as the American cohort study used a cut-point of 6 or above that enabled only moderate or severe symptoms to be included as a case. Finally, in another Scandinavian study (NUDATA) of almost 7,000 office workers with the average time spent at the computer reported to be 23 hr/week, moderate to severe symptoms were recorded if they occurred within the past 7 days [Kryger et al., 2003; Brandt et al., 2004]. For forearm pain 4% symptoms prevalence was reported, 4% for neck, and 3% for shoulder. This is substantially less than that reported in the current study likely due to a more sensitive case definition seeking participants with moderate or more severe pain. We believe the observed findings of greater symptoms prevalence are related to a less sensitive case definition relative to previous research on populations already in the workforce.

Differences in exposure classification also make it difficult to compare across studies when trying to evaluate associations between computing exposures and symptoms. The NUDATA study differentiated computer use exposures into mouse use and keyboard use and found generally an increase in input device use (noticeably for mouse use) was associated with an increase in symptoms. However, due to the different categorizations of computer use among the cohorts examined in addition to the current cross-sectional study, it is difficult to compare the association of computing with symptoms. A prospective cohort study conducted among college students that will allow for such comparisons is underway.

In this study we try to bridge findings from two undergraduate populations at two geographically distinct universities with a graduate student population at still another geographically distinct university. Each study had about 30% non-participation from the target population, so, if there were even slight differences in individual characteristics and symptoms/limitations from one study to the next, differences that were not true would be further disparate once all four study populations were accounted for. However, both study populations at the same institution (the current study and that of SWU) had similar findings despite their differences in undergraduate/graduate classification. Our generally comparable findings across these populations increase the generalizability of computing-related pain among college students.

One limitation to this study is its cross-sectional design. It is impossible to evaluate a temporal relationship between the exposure and outcome as they are ascertained at the same moment. Therefore, this precludes any statements of causality. However, it provides an opportunity to identify potential risk factors that can be evaluated in a prospective cohort study designed to determine causal relationships. Another possible limitation is selection bias. Sixty percent of eligible graduate students participated in the study; the majority of the remaining graduate students were doing summer fellowships with companies elsewhere in the United States or internationally. If these students had a different symptoms prevalence or computer use experience compared to those who participated, then there likely would be some level of selection bias.

Another limitation to this study is the one-dimensional use of computing duration in exploring an association with upper extremity pain after computing. As we were constrained by the previous study conducted at WU, which was administered by phone and was limited to asking about weekly computer use per year of graduate school, our findings were meant to be exploratory and preliminary. The intent was to make comparisons with another graduate student population rather than draw substantive conclusions about weekly computer use and upper extremity musculoskeletal symptoms/disorders. Findings in the current study can neither provide any insight as to what level these exposures may be present nor describe any associations they may have with reported symptoms. However, we found similar weekly computing patterns to the other WU graduate student population, which justified the inclusion of the more time-intensive and costly direct and observational measurement methods of computing-related exposures, in addition to including posture assessments in a prospective cohort study recently completed in an undergraduate student population. From the cohort study we plan to make conclusions regarding the role of non-neutral computing postures and computing duration in predicting upper extremity musculoskeletal symptoms.

Overall, general findings of this study were very similar to those of the previous undergraduate studies. There were not enough women in the study for observed gender differences to be statistically significant, however they were in parallel with the two previous undergraduate studies. No differences were observed by race/ethnicity. Similar to the previous study on graduate engineering students, number of years in graduate school and hours of computer use were associated with computing-related pain. Future research regarding the epidemiology of computing-related upper extremities should include both student populations. Ergonomic intervention programs designed to be taught by undergraduates for the benefit of undergraduates should focus on graduate student populations as well [Robertson et al., 2002].

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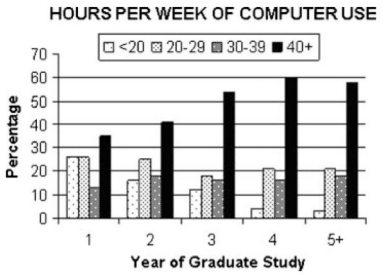

FIGURE 1.
Proportion of weekly hours of computer use for each year of graduate school.

TABLE I

General Characteristics of Study Population

	N (%)	Pain with computing N (%)	No pain with computing N (%)
Total	166 (100)	91 (55)	74 (45)
Men	125 (75)	66 (73)	59 (79)
Women	41 (25)	25 (27)	16 (21)
Age			
21–25	64 (39)	34 (37)	30 (40)
26–30	84 (51)	45 (49)	39 (52)
31+	16 (10)	11 (12)	5 (7)
Number of years in graduate school			
1	33 (20)	14 (15)	20 (27)
2	28 (17)	15 (16)	12 (16)
3	40 (24)	26 (29)	13 (17)
4	28 (17)	16 (18)	11 (15)
5 or more	37 (22)	19 (21)	17 (23)
Play a musical instrument	47 (28)	23 (25)	24 (32)
Play a sports activity	115 (69)	61 (67)	54 (72)
Self-reported overall health			
Excellent	59 (36)	28 (31)	31 (41)
Very good	70 (42)	42 (46)	28 (37)
Good, fair, or poor	37 (22)	21 (23)	16 (21)
Mental health index (MHI-5)[a]	76 (17.6)	76 (16.4)	76 (19.1)

[a]Mean (standard deviation).

TABLE II

Prevalence and Demographic Distribution of Computer-Related Symptoms, Self-Reported Functional Limitation, Academic Impact, Medication use, and Health Services Utilization

		Gender (%)		Racial/ethnic minority (%)[a]	
	Overall sample (%) (n =166)	**Female (n =41)**	**Male (n =125)**	**Yes (n =80)**	**No (n =74)**
Current upper extremity pain with computing	55	61	53	49	62
With >1hr computing	45	44	46	41	49
With ≤1hr computing	10	17	7	8	14
Brigham symptom severity scale score >0	70	68	71	65	78
Student functional limitation scale score >0	55	60	54	58	49
Academic impact index score >0	3	5	2	4	1
MHI-5 score (Mean, SD)	75.8 (17.6)	73.9 (17.6)	76.4 (17.7)	75.8 (18.2)	75.1 (17.3)
Medication use for computer-related pain/discomfort	23	37*	19	24	24
Health services utilization for computer-related pain/discomfort	16	20	15	22	12

*P <0.05, by Fisher's exact test, females compared with males.

[a]Missing data: Racial/ethnic minority status, n =12.

TABLE III

Overall Prevalence and Gender-Specific Prevalence of Computer-Related Discomfort/Pain by Anatomic Site

		Female and male students reporting discomfort/pain in this location (%)		Minority and non-minority students reporting discomfort/pain in this location (%)[a]		Female minority students reporting discomfort/pain in this location (%)[a]	
Site of pain	**Overall prevalence (%)**	**Female (n =41)**	**Male (n =125)**	**Minority (n =80)**	**Non-minority (n =74)**	**Femaleminority (n =22)**	**Other[b] (n =140)**
Neck	62	75	58	66	59	71	61
Shoulder	50	60	47	51	47	57	49
Upper arm	9	13	8	10	6	20*	8
Elbow	22	28	20	23	21	29	20
Forearm	28	28	27	22*	35	20	28
Wrist	52	56	51	46	60	50	52
Hand	35	41	34	29	42	40	34
Fingers	35	34	35	33	35	32	34

*P <0.10, by Fisher's Exact Test, comparing females minority students with others and minority with non-minority students.

[a]Missing data: Race/ethnicity, n =12; Gender and race/ethnicity, n =4.

[b]Other refers to male minority and male/female non-minority students.

TABLE IV

Relationship of Computer-Related Symptoms to Self-Reported Functional Limitation and Academic Impact, Medication use, and Health Services Utilization

	Among students with no current computer use-related upper extremity symptoms: (%) (n =75)	Among students with any current computer use-related upper extremity symptoms: (%) (n =91)	Breakdown of students with any computer use-related upper extremity symptoms by time of computing	
			Symptoms with >1hr computing: (%) (n =84)	Symptoms with ≤1hr computing: (%)(n =7)
Student functional limitation scale score >0	32	74**	70	94*
Academic impact index score >0	1	4	4	6
Medication use for computer-related pain/ discomfort	10	34**	32	44
Health services utilization for computer-related pain/ discomfort	12	20	12	60**

* *P* <0.10 by Fisher's exact test comparing symptoms occurring within an hour with those occurring after an hour.

** *P* <0.01 by Fisher's exact test comparing symptomatic students with asymptomatic students and symptoms occurring within an hour with those occurring after an hour.

TABLE V

Comparison of Results With Previous Studies: Current Study (Graduate, SWU), Jenkins et al. [2007] (Undergraduate, SWU), Hupert et al. [2004] (Undergraduate, NEU), and Schlossberg et al. [2004] (Graduate, WU)

	Graduate SWU* (n =166)	Undergraduate		Graduate WU (n =206)
		SWU (n =116)	NEU (n =194)	
Current upper extremity pain with computing	55[a]	54&check	42	N/A**
With >1hr computing	45	51&check	31	N/A
With ≤1hr computing	10	3&check	10&check	N/A
Student functional limitations	55	62&check	55&check	61&check
Medication use	23	27&check	23&check	N/A
Health services utilization	16	15&check	16&check	N/A
Body sites with most prevalent pain:				
Neck/wrist	1st/2nd	1st/3rd&check	2nd/1st&check	N/A
Shoulder	3rd	2nd&check	4th	N/A
Students experiencing any pain with computing more likely to experience student functioning limitations	74	94	85&check	N/A

✓Indicates similar findings (differences within 10% points or within top three ranking) as the current study.

[a] Percent.

* Current study.

** N/A indicates data not available.