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College students and computers: Assessment of usage patterns and musculoskeletal discomfort

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Abstract. A limited number of studies have focused on computer-use-related MSDs in college students, though risk factor exposure may be similar to that of workers who use computers. This study examined computer use patterns of college students, and made comparisons to a group of previously studied computer-using professionals. 234 students completed a web-based questionnaire concerning computer use habits and physical discomfort respondents specifically associated with computer use. As a group, students reported their computer use to be at least 'Somewhat likely' 18 out of 24 h/day, compared to 12 h for the professionals. Students reported more uninterrupted work behaviours than the professionals. Younger graduate students reported 33.7 average weekly computing hours, similar to hours reported by younger professionals. Students generally reported more frequent upper extremity discomfort than the professionals. Frequent assumption of awkward postures was associated with frequent discomfort. The findings signal a need for intervention, including, training and education, prior to entry into the workforce. Students are future workers, and so it is important to determine whether their increasing exposure to computers, *prior to* entering the workforce, may make it so they enter already injured or do not enter their chosen profession due to upper extremity MSDs.

Keywords: Computer, VDT, college students, musculoskeletal discomfort

1. Introduction

1.1. Background

Worldwide personal computer (PC) use has grown from 6.5 users per 1,000 people in 1985 to 663 per 1,000 in 2002 [9]. PCs per capita in the U.S. reached 80% in 2006 and are expected to reach 98% by 2012 [10]. No longer just used in office settings, computers are ubiquitous. They are utilized in many types of work settings, as well as in public facilities, such as libraries, and in retail stores for customer use. Use in schools and homes is also growing, which means that computer use is no longer just an activity of adult workers. Computer use may actually be more prevalent among some groups of non-workers, namely students, than among some adults who use computers for work. To illustrate this point, a study at the University of Massachusetts revealed that the proportion of students with no experience with computers fell to almost zero over a five yr period in the early 1990s [29].

As computers expand our horizons, research and reports show some negative effects associated with computer use, in the form of musculoskeletal discomfort

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and disorders (MSDs). Muscle pain and tendonitis tend to be the most common diagnoses reported in epidemiological studies of VDT users [13,14]. Carpal tunnel syndrome is also known to be present in populations of VDT users [47]. Carpal tunnel syndrome is an important health outcome due to the significant number of lost work days with which it is associated (median lost work days were 27 in the US in 2006; BLS, 2006, Table R67). It is interesting to note that 2.2% of carpal tunnel syndrome cases and 6.3% of tendonitis cases reported in 2006 involved workers younger than 25 years old (BLS, 2006, Table R50). Risk factors that are singularly identified to contribute to MSDs are repetition, duration, force, and posture, and there is strong evidence that jobs that impose combinations of these factors increase a worker's risk for developing MSDs [5].

Numerous studies of adult workers have found associations between computer use and musculoskeletal discomfort [6,18,21,25,28,30,41,45,46]. Repeatedly, temporal and postural factors have been associated with musculoskeletal symptoms and/or disorders in workers who use computers. In a prospective study, Marcus et al. [32] showed that increasing the number of hours per week spent keying and having the keyboard above elbow height increased the reporting of musculoskeletal symptoms (MSS) and MSDs as determined by physical exam. In a cross-sectional study, Bergqvist et al. [3] showed that limited rest break opportunity and frequent overtime, along with a poor match between elbow height and keyboard height, non-neutral postures, non-use of arm support, and limited task flexibility resulting in postural fixity, were related to discomfort and MSD diagnosis through a physical examination.

Working under hard deadlines has also been identified as a potential risk factor for MSD development. In a cross-sectional study of newspaper employees, upper extremity disorders and work-related factors were evaluated through a survey of 973 participants [4]. The number of hours spent under a deadline and reported hours of typing related significantly to musculoskeletal risks. Fifty-three percent of the employees reported spending 10 hours or more under a deadline, and this factor was a significant predictor of neck and hand/wrist MSD. The researchers implied that the increased risk could be associated with the deadline, creating increased psychological stress, increased musculoskeletal tension, a more constrained posture, or fewer breaks being taken by the employees. Another major contributor was the number of hours reported typing. A dose-response relationship was identified. A two-fold increase in risk was determined for those who typed 6–8 hr/day, in comparison to those who typed 0–2 hr/day. An odds ratio of 3.3 was determined for those who typed more than 8 hr/day. This study also included a random sampling of the respondents to observe their actual typing hours. From the larger group, 76 workers were chosen. For those with hand/wrist symptoms, reported typing hours were 4.5 (sd 2.6), while actual observed typing hours were 2.5 (sd 1.4). In the non-case referent group, reported typing hours were 3.9 (sd 2.1), but actual observed typing hours were 1.9 (sd 0.9) [4]. Although the workers tended to over-report their computing hours, the variation remained consistent between the two groups.

Some interventions in the office worker population have been shown to be effective in reducing VDT user discomfort [1,38,47]. In one intervention study of adult VDT workers, introduction of a preset tilt down keyboard tray showed significant improvements in wrist posture, seated posture, and a reduction in upper body musculoskeletal discomfort, when compared with a control group that kept their current workstation setup [16]. In another study, incorporating rest breaks of 5 min every hour, in addition to the conventional two-fifteen minute breaks, was shown to reduce discomfort [12].

The number of studies investigating children and their computer use is growing. Harris and Straker [15] found that 60% of a sample of 271 students, aged 10–17 years, reported discomfort with using their laptop computers. An association of discomfort was found with school grade levels, as well as time using the laptop. The average daily usage of these children's laptops was 3.2 hours, with a weekly average usage of 16.9 hours. In one sitting, the mean minimum time before a break was 11.5 minutes, but the maximum use time before a break averaged 101.9 minutes. There was a statistically significant association found between mean maximum time on task and discomfort while using the computer.

In a survey of 382 high school students, 28% reported hand discomfort after using the computer, 40% reported neck/back pain, and 41% reported general body pain [24]. Four percent had been self-diagnosed or medically diagnosed with carpal tunnel syndrome, and 2.5% sought medical care for their pain. Jones and Orr further concluded that since high school students are establishing their lifestyle activities and patterns, the increased computer use at a younger age may increase the prevalence and trauma associated with computer use as students become older.

Another study emphasized the importance of educating students about MSD and teaching students about healthy computing. 'Students are at risks for RSIs (repetitive strain injuries) because of student behavior, laboratory arrangements, a lack of emphasis on posture in the curriculum, and the attitudes/perceptions of faculty and administrators' [39]. In their study of students in grades 2–12, of those who experienced pain while using a computer, 67% did not stop in spite of the pain, and 73% did not tell a parent about their pain. In their conclusion, Royster and Yearout urged three objectives: [the] revision of the current curriculum to include information concerning the potential [danger] of repetitive stress injuries and additional emphasis on postures; additional guidelines concerning computer workstation dimensions and laboratory set-up; and increased funding designated specifically for the purchase of ergonomic computer furniture. Currently, they suggested, computer literacy continues to receive a greater emphasis than ergonomics.

In a study involving students in the 6^{th} and 8^{th} grades, five different mouse and keyboard configurations were offered, one including a keyboard and mouse tray with adjustable features [31]. The adjustable features configuration had a positive effect on posture, and the students most frequently chose this option as a more comfortable and easier set-up, demonstrating that intervention benefits may extend beyond adult computer users to child users, as well.

An understudied segment of the population that may have an elevated risk for developing MSDs, in association with computer use, is college students. The National Center for Education Statistics reported the fall enrollment in post-secondary institutions in 1999 to be over 14 million, with enrollment expected to exceed 17 million by 2011 [36]. The use of computers by college students is also expanding, with some institutions requiring students to own a computer. Only a few studies have investigated college students' computer use, from an ergonomics perspective.

A survey conducted by Alexander [2] aimed at assessing the ergonomic knowledge of college students in areas of general computer awareness, medical health and safety, radiation, computer workstation and environment, and computer workstation technique, found correct response rates of 20% or less among the respondents.

From San Francisco State University, a questionnaire investigating the possible association of computer use and discomfort received 95 student responses [37]. The students reported an average daily computer usage of 2.9 hours, and nearly all students reported some level of discomfort associated with computing. Eighty-one percent of the students reported using techniques in order to 'feel better', such as stretching, taking breaks, and modifying their position or posture, but researchers speculated that these tasks were done only as a relief to discomfort and not as informed preventive measures. Students also reported extreme time pressure on some assignments, and the researchers felt that even if the computing activity on these assignments was short that stress could increase discomfort. However, no significant correlation between hours worked and reported discomfort were found in this study. The researchers concluded that healthy computing programs for the employees at the University should be integrated into the student population as well [37].

A more structured study, with a 96% response rate, found 53% of a class of graduating seniors experienced symptoms in the upper extremity (UE) when using a computer. Symptoms of UEMSDs were associated with being female, a computer science concentration, and self-reported computing for more than 20 hours per week [26]. College students' musculoskeletal discomfort is manifested in tangible ways, including interference or difficulty with performing personal or computer-related tasks. For example, 36% of a sample of undergraduates reported difficulty with typing a 10 page assignment, due to UE discomfort [27].

Katz and colleagues also investigated how UE disorders affected symptomatic graduate and undergraduate students [11]. The students reported that computers have an essential role in their academic, social, and personal lives. One of the participants described using a computer as early as age 5. Having an UE disorder had negative impacts on physical and emotional well being, including altering career aspirations to paths with less computer intensive obligations. Students' expectations and perceptions of medical care providers were overall negative. Most students reported that they were told to discontinue computer use, and students felt that this suggestion was not realistic. Students also reported a delay in seeking medical treatment, because they did not feel their symptoms were serious enough, they were unsure of quality of medical care, or they were 'busy' with other parts of their lives. Of the two groups, graduate students in the study reported seeking medical care later than undergraduates. The groups' recommendations were for attention to early interventions instead of directing efforts toward those who already experience symptoms. The students believed information about MSDs needed to reach all students, and special emphasis needed to be made to ensure they understand the chronic nature of MSDs if left untreated. Suggestions were made for complete ergonomic evaluations of computer workstations, along with providing checklists of information in labs and examples of ergonomic adaptations of current workstations, along with ergonomic equipment in labs, for students to try [11].

To determine the prevalence of symptoms related to computer use in college students, Hupert et al. [19] asked students if they had experienced upper extremity pain while computing, within the last two weeks. Forty-two percent reported pain or discomfort and 41% indicated that this pain or discomfort had limited their abilities to perform academic or extra-curricular activities. Only 16% reported seeking medical attention; 23% reported taking medication for the symptoms. This study was replicated in another college student population in 2007. The results showed some increases in the percentage of college students reporting symptoms (54%) and the percentage of students reporting that the discomfort or pain limited their abilities to perform academic or extra-curricular activities (67%) [20]. Eighty-six percent of a small sample of participating undergraduates reported ever experiencing upper extremity pain or discomfort while working on the computer or after working on the computer [33].

Although it seems apparent to many that computer users are at risk of developing MSDs, there remains a low level of awareness of college students' risks, as compared with professional workers. This signals a need for more research, among other actions. In those studies involving college students, few included a diverse population of graduate and undergraduate students. Usage patterns of college students have only been quantified in general terms of weekly or average daily computer usage. Computer use on specific days, such as during the week versus the weekend, has not been described in available research; the days that college students use computers could vary depending on a variety of factors, such as academic concentration or class standing. Patterns of use throughout the day have not been described (use/break patterns). With only a limited number of studies evaluating college students, the research need is clear. College students are the incoming work force. Compared to the current office worker, today's students started to use computers much earlier in their lives, and will continue to surpass the current typical office worker's lifetime usage by the time he/she is only midway through his/her career [31].

1.2. Specific aims of the current study

The specific aims of the current work were to 1) develop, among different groups of college students, profiles of computer use patterns and musculoskeletal discomfort specifically associated with computer use, 2) compare student use patterns with similarly obtained patterns from professionals that use computers, and 3) identify associations between patterns of use and musculoskeletal discomfort. Since musculoskeletal discomfort and disorders are a concern for workers who use computers, it is appropriate to determine whether or not college students may be entering the workforce in a healthy state or entering with existing musculoskeletal problems that might be assumed to worsen or remain at a chronic level if they continue to use computers in their professional careers. Also, college students could be developing poor computing habits and some type of intervention incorporated into the university environment could be helpful to reduce the likelihood of poor computing habits.

Based on the existing relevant literature, an investigational model of student computer use and musculoskeletal discomfort was developed to guide the design of the current study (see Fig. 1). The first block partitions the sample of computer users into simple categories of 'professionals' and 'students', and then subdivides the students by major and by graduate/undergraduate status. The second major block illustrates an emphasis on developing more refined use profiles by considering separately the weekday, weekend, and overall weekly use, as well as a more refined picture of the hour-to-hour use of computers. Finally, this model also examines patterns of continuous computer use (the amount of time sitting at a computer before taking a break), as previous research has shown reduced discomfort with increased break frequency.

2. Methods

The surveys and protocols for this study and the study of the professional workers (PW) were approved by the appropriate human subjects protection review boards of the authors' institutions. All participants were required to provide informed consent prior to participating in the studies.

2.1. Subjects

Students from North Carolina State University, The Ohio State University, and The University of South Florida, were recruited to participate in a survey. Convenience sampling was utilized: students were recruited from classes of faculty members known to the au-

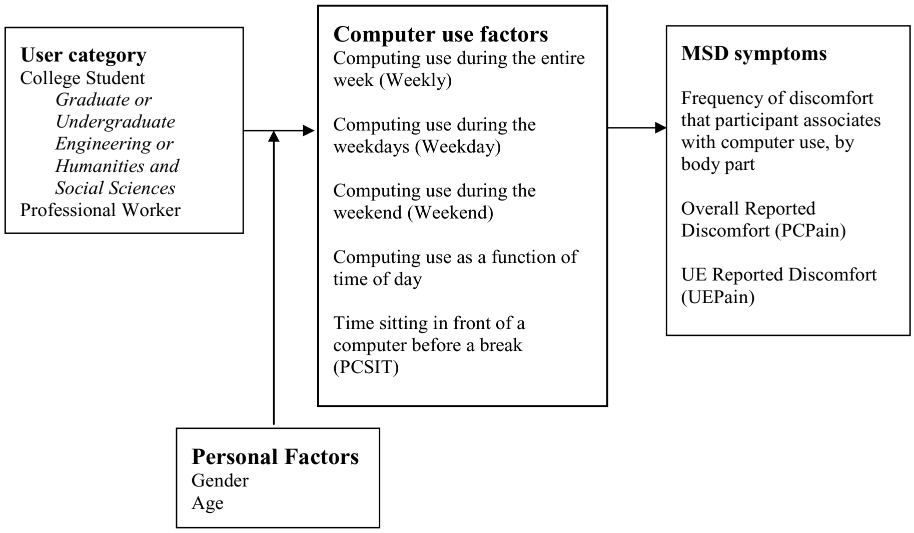

Fig. 1. Graphical representation of current study.

thors, and as they entered or exited from campus computer labs. Students received no compensation for their participation. Approximately 700 students were invited to participate in the study. Of those 700 students, 655 (93%) accepted or requested a card that gave them the survey's URL and a unique access code for the web-based survey. 267 surveys were completed, for a response rate of 38%. Due to duplication, neglect, or errors in responses, 26 responses were excluded from the analyses.

2.2. Survey instrument

The questionnaire used in the current study was based on one used to study professional workers who use computers for work [42]. A subset of questions from that research was adopted for the current study. The questions focused on computer use in relation to location, duration, frequency, posture, and discomfort. The single question on discomfort was worded as follows: When using the computer, or after using it, how often do you experience any physical discomfort (such as stiffness, soreness, aching, numbness, tingling, pain, etc) in the areas listed below? A list of 13 body regions followed, and participants selected one of five frequency responses (from *Never* to *Almost always*) for each body region.

Some questions were tailored specifically to suit students, such as one concerning locations of computer use, which provided responses that included home, campus home, computer lab, and library. Computing habits queried included computer use measured in hours per day, software application usage, and typical computing time frames during each day, selected from a table of two-hour time divisions (8–10 am, 10 – noon, etc). Duration of computer use before taking a break was determined by asking students how often they sit continuously while using the computer for a specific amount of time (more than X min, where X = 30, 60, 90, and 120). Response choices ranged from *Never* to *Almost always*. Respondents were also asked to describe how often they found themselves assuming awkward postures while using a computer. Demographic information collected from the students included age, gender, class standing, major, and a question on when they began using computers. The instrument has a 7.8 grade level readability, as measured by the Flesch-Kincaid readability scale. The survey instrument is contained in Appendix C of the thesis by Noack [35].

2.2.1. Response processing and compacting

Categories of class major and class standing were condensed. Responses were divided into either Engineering (Eng) or Humanities and Social Sciences (HSS). Seven responses were dropped, because they did not fit into these categories. Class standing was condensed to undergraduate or graduate.

In estimating hours worked per day on a computer, answers from those students who chose to provide a range of hours, rather than a single value, were converted to an average of the provided range, and a maximum and minimum, which equaled the ends of the range. For weekly computing hours, averages for each day (Mon-Sun) were summed to provide an estimate of weekly computing hours. For weekday computing hours, only the average hours of Monday thru Friday were summed. Weekend use was taken as the summed average computing hours for Saturday and Sunday.

From the set of four questions that asked how likely the students were to sit continuously working at the computer for X amount of time before taking a break, a weighted average of the four individual sitting time descriptions was calculated, to provide a single score (PCSITSCR), that ranged from 1–5 [42].

For characterizing frequent discomfort specifically associated with use of a computer, the number body parts for which a subject reported discomfort occurring *Quite often* or *Almost always* was summed. This was referred to as the PCPain score [42]. Frequent discomfort in the upper extremity (including the neck and upper back) was also computed, and was referred to as UEPain.

2.3. Independent variables

When just considering the student data, the independent variables were Class (graduate or undergraduate), Major (Eng. v. HSS), and Gender. The interaction between Class and Major was also considered. Other second order interactions were not considered. When comparing the college student (CS) and professional workers' (PW) data, the independent variables were Category (CS v. PW) and Gender. The interaction term was also included in the models. Due to the potential association between age and MSD, when making statistical comparisons between the CS and PW, only data from subjects under 35 years of age were utilized from both groups.

2.4. Dependent variables

The dependent variables of interest were based on questions about the participants' computer use in the areas of frequency, duration, posture, discomfort, demographic information, and previous computing experience. Some of these responses were evaluated qualitatively in descriptive statistics, while others were formally addressed via statistical analyses.

2.5. Statistical analysis

The survey produced ratio and ordinal data. JMP (SAS, Cary NC) was used for analysis. Throughout the analysis, a probability of less than 0.05 indicated a significant effect. Residuals were examined for normality (only moderate departures found) and homogeneity of variance (assumption met), as prescribed by Montgomery [34]. The data for reported computing hours were analyzed through a one-way analysis of variance (ANOVA). The ANOVA procedure was used to evaluate differences in computing hours among the groups of students, and comparisons were also made between the professional workers and the students. The data set used to test these latter differences was the data set that eliminated those respondents over 34 years of age. Non-parametric tests were used to compare the groups where ordinal scales were used. The Wald Chi-Squared test was used for the analysis that tested the effects of the independent variables on PCPain, UEPain, and PCSITSCR.

3. Results

Descriptive statistics are presented first, followed by statistical analyses of musculoskeletal discomfort and potential risk factors. Statistical comparisons between CS and PW utilize only the data for participants under age 35, in both groups.

3.1. Demographics

Basic demographic information (age, gender, and race/ethnicity) is provided in Table 1, for all participants. As a point of interest, almost half of the CS (45%) began using computers prior to starting high school, while this was the case for only 11% of the PW. CS distribution by class standing and major is presented in Table 2.

When the data were reduced to just those subjects under 35, there remained 201 students (mean age of 23.6 years, s.d. 3.6; 121 females and 80 males) and 60 professionals (mean age of 30.5 years, s.d. 2.9; 30 females and 30 males).

3.2. Computer use practices

102 students reported using both desktop (DPC) and notebook (NPC) computers. Another 122 students reported only using DPCs, but just 10 used only NPCs. 91% of the students reported that they used a computer every day in a typical week. The likelihood of computer use for each day during the week is depicted in Fig. 2 for the CS. Similarly, 91% of the PW were classified as 'heavy users', meaning that they used their computers

Table 1
Demographic information for the CS and PW: age, gender, and race/ethnicity. Number of responses to each question provides sample size information

	College students n = 234	N for CS question	Professional workers n = 302	N for PW question
Mean age, years (sd)	25.2 (6.4)	219	44.4 (9.9)	300
Gender, n (%)	87 Males (37%)	234	181 Males (61%)	299
	147 Females (63%)		118 Females (39%)	
Race/ethnicity, n (%)	179 Caucasian (76%)	232	272 Caucasian (90%)	297
	31 Asian (13%)		8 Asian (3%)	
	27 Other (11%)		23 Other (7%)	

Table 2
Distribution of all student subjects by class standing and college major

	Engineering	Humanities & social sciences
Undergraduate	76	64
Graduate	49	45

for work on all, or at least the vast majority, of days they worked.

Both CS and PW were asked about the likelihood of using a computer during specific time periods throughout the day. For each two hour time period, the response choices were the same as those listed in Fig. 2. Figure 3, depicting *Very likely* responses, shows that the professional workers appear to concentrate their computer use during normal business hours, while the college students' computing hours shift towards the evening hours. The CS, as a group, were at least *Somewhat likely* to use a computer for 9 of the 12 2-hr time slots, while that number was 6 of 12 for the PW. Hours of computer use during the week and on weekends are presented in Table 3. Together, this information indicates that college students may spread out their computer use over more of the day, and then have less extended recovery time (2:00 a.m. – 8:00 a.m.) between computing hours, compared to the professional workers (6:00 p.m. – 6:00 a.m.).

3.3. Musculoskeletal discomfort

PCPain and UEPain differed only between male and female students, and was not a function of Class or Major. Average PCPain was 2.4 ($sd = 2.6$) for females and 1.2 ($sd = 1.5$) for males ($p = 0.0032$). Average UEPain was 2.0 ($sd = 2.1$) for females and 1.1 ($sd = 1.3$) for males ($p = 0.0042$).

PCPain did not differ by category (that is between the CS and PW; the analysis was limited to participants under 35 years of age), but did still differ by Gender ($p = 0.0004$). UEPain differed by both Category ($p = 0.0008$) and Gender ($p = 0.0017$), though there was no interaction between these factors. The data are summarized in Table 4.

A subsequent examination of differences in frequency of discomfort by body part, provided an explanation for the effect of category on UEPain (see Fig. 4). Compared to the professionals, greater percentages of students experienced frequent discomfort in several areas that contribute to the UEPain score: left and right forearm-elbow regions, the right shoulder, and the neck. By contrast, greater percentages of professionals experienced more frequent discomfort in the low back and the eyes, than did the students. The difference for the eyes is particularly striking: very few students reported frequent eye discomfort, while the prevalence for PW exceeded 30 percent.

3.4. Hours of computer use

For the college students, hours of computer use differed only by Class, and not by Major, Gender, or Class x Major. Hours of computer use for graduate students exceeded those of undergraduates for weekday hours ($p = 0.0022$), weekend hours ($p = 0.0228$), and total weekly hours ($p = 0.0021$). As can be seen in Table 3, average hours of use are similar between graduate students and PW. If treated as a single group, however, total hours per week of use for CS are less than PW ($p = 0.0061$; 29.1, $sd = 15.6$, 35.1, $sd = 12.6$, respectively).

No statistically significant association was found between students' hours of computer use and discomfort. However, graphical representations of the data revealed some tendency for fewer hours of computer use to correspond with greater UEPain and PCPain. This is may be the result of those with more frequent pain limiting their use of computers. As an anecdotal example of this, no students with PCPain >5 reported usinga computer for more than 12 hours on the weekend, whereas weekend use for 17 of the 194 students with PCPain <5 ranged from 13–28 reported hours.

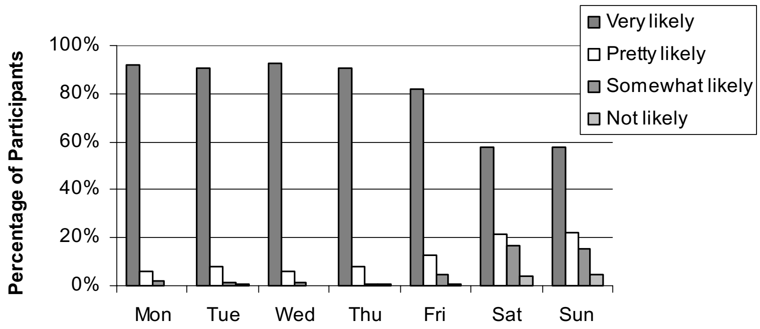

Fig. 2. Likelihood of college student computer use throughout the week.

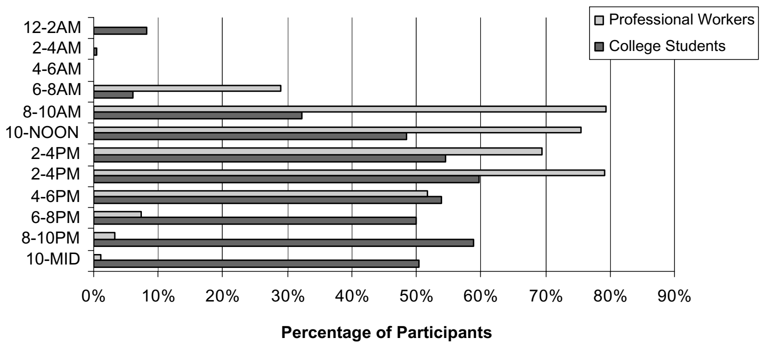

Fig. 3. Percentage of participants who were *Very likely* to use a computer at specific intervals during the day.

Table 3
Weekday and weekend hours of computer use reported by participants; means and standard deviations are presented

	Undergraduate	Graduate	PW
Weekday, hrs			
All participants	20.4 (10.9)	25.3 (12.8)	26.6 (9.0)
<35 yrs	20.4 (11.2)	25.7 (12.8)	29.3 (9.4)
Weekend, hrs			
All participants	6.2 (4.1)	7.6 (5.5)	5.3 (6.4)
<35 yrs	6.2 (4.2)	8.0 (5.7)	6.4 (7.4)

Table 4
Average PCPain and UEPain scores (and standard deviations), as a function of gender and study category

	College Students		Professionals	
	Female	Male	Female	Male
PCPain (possible range 0–13)	2.4 (2.5)	1.2 (1.5)	2.3 (2.5)	0.9 (1.2)
UEPain (possible range 0–8)	2.0 (2.0)	1.0 (1.3)	1.2 (1.6)	0.4 (0.8)

3.5. *Continuous sitting*

Class had a significant effect on the PCSITSCR composite variable ($p = 0.0004$), while Gender and Major did not. Graduate students tended to sit for more frequent, and/or longer, uninterrupted periods of time at a computer than did undergraduates (4.0 ($sd = 0.6$) v. 3.6 ($sd = 0.7$), respectively). As a single group, CS had a higher PCSITSCR than did the PW (3.8 ($sd = 0.7$) v. 3.2 ($sd = 0.8$), respectively).

Within the college students, the correlation between the reported discomfort (PCPain) and likelihood of continuously sitting (PCSITSCR) was 0.35 ($p < 0.0001$), suggesting a relationship between static positioning and discomfort. The correlation between the reported dis-

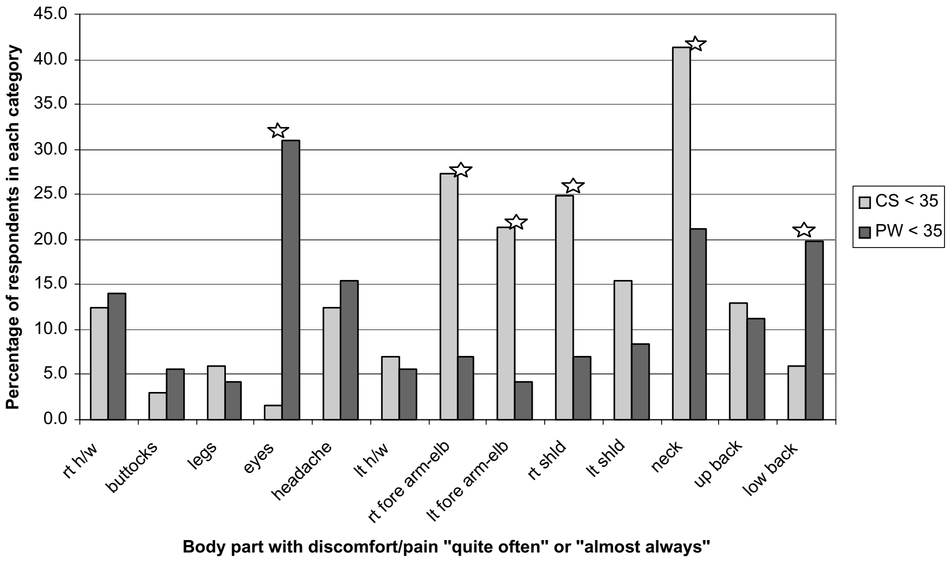

Fig. 4. Percentage of respondents in each category who reported frequent discomfort. Stars indicate significant differences between groups.

Table 5
Percentage of respondents who were *Quite often* or *Almost always* aware of assuming awkward postures while using a computer

	College students	Professionals
While using a desktop computer	30.4%	29.5%
While using a notebook computer	17.9%	21.3%

comfort and likelihood of continuously sitting was similar when all subjects under 35 were included 0.38 ($p < 0.0001$).

3.6. Awkward postures

Students reported being aware of assuming awkward postures when using both desktop and notebook computers. Table 5 presents dichotomized data for the CS and PW, which show similar percentages, between the two groups, of those reporting frequent awkward postures (answered either *Quite often* or *Almost always*) for DPC and NPC use.

Frequent adoption of awkward postures was associated with frequent discomfort, expressed through the PCPain score ($p = 0.009$). Figure 5 illustrates that when students are compared on the basis of more frequent or less frequent assumption of awkward postures while using a desktop computer, a greater percentage of the former group experiences frequent discomfort in at least one body part (75% with PCPain >0), when compared with the latter group (56%). Results were similar for notebook use.

4. Discussion

4.1. Musculoskeletal discomfort

The college students in this study reported experiencing frequent musculoskeletal discomfort specifically associated with the activity of using computers. Female students in this study reported a higher frequency of discomfort associated with using a computer than the male participants. This is consistent with previous research, where gender was also found to be a significant factor [19,20,40]. In addition to gender, Katz et al. [26] found academic concentration (major), residential house, hours of computer use each week and participation in intercollegiate athletics was associated with UE discomfort specifically associated with computer use. In contrast, and similar to the current study, Hupert et al. [19] did not find major to be significant. The study by Katz et al. [27], did not include all areas of the body to indicate discomfort – only the UE was described. The current research inquired about discomfort in the neck, trunk, and legs, as well as the UE and found frequent discomfort in the neck region to be the most common site of frequent discomfort for

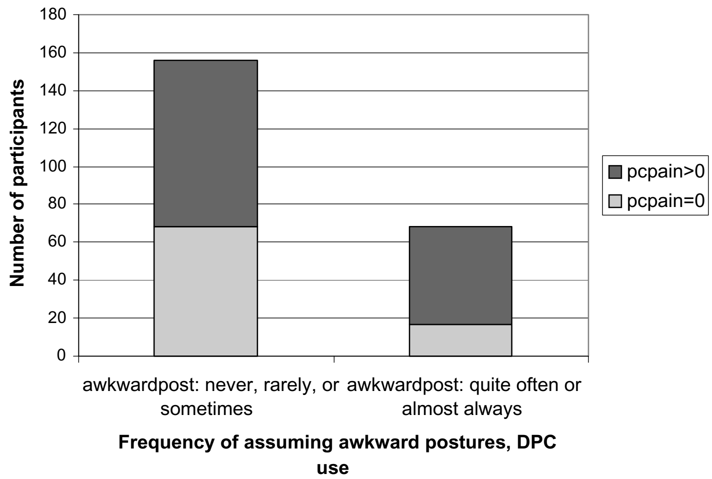

Fig. 5. Association between frequent assumption of awkward postures while using a DPC and frequent discomfort in at least one body part (PCPain >0).

this sample of college students; this agrees with other recent studies [19,20,33]. Previous studies of workers who use computers have also found more discomfort in females [7,22,32,42].

In the current study, the finding that UEPain was greater in college students' than in the PW was unexpected. Since office workers reported spending more hours using a computer, if a dose-response relationship existed between hours of use and discomfort, one would expect that UEPain would have been higher for the PW. The higher level of UE discomfort reported by college students could be due to varying work environments, however. College students use various computers in a variety of locations: in computer labs, the library, and/or their homes. The configurations of the computers in public spaces on campus may not be suitable for some portion of users. Based on appearance, the priorities in computer labs are providing the maximum number of workstations, with the highest level of processing speed and software availability (for the funds available). As a result, college students must adapt to the conditions of the workstation, balancing books and papers in the limited space provided, and assuming whatever posture possible. In the current study, students did report assuming awkward postures while using computers, and an association was found between frequent adoption of awkward postures and frequent discomfort in one or more body parts.

Poor workstation design has been linked to discomfort in a number of studies. However, the availability of adjustable furniture in college computer labs may be limited or non-existent depending on funding priorities [39,49]. Studies have shown an association between limited or insufficient table space and neck/shoulder discomforts; other associations of neck/shoulder discomfort include the high positioning of the keyboard and VDT [3]. Along with discomfort, tension neck syndrome diagnosis has been associated with insufficient table space, and arm/hand discomfort has been associated with non-neutral or extreme hand positions [3]. Further, college students may not feel the urgency to take measures to prevent pain. Cortés et al. [11] in their focus groups of symptomatic college students, found that, in general, the college students "did not feel their symptoms were serious enough" to report.

4.2. Temporal and postural aspects of computer use

In this study, the primary difference between graduate and undergraduate students was in the number of hours of computer use, although average weekly hours of use by both groups exceeded 20 hours per week, the limiting value that Katz et al. [27] identified as a risk factor in their research. Unlike that study, however, no relationship could be identified between hours of use and discomfort in the current study. This may be due to the cross-sectional nature of the study. In retrospect, it would have been useful to include a question about any changes students may have made in their use of computers as a result of musculoskeletal discomfort, as observed in another study [49].

Compared with the current study, fewer daily hours of use have been reported in other studies of undergraduates (2.9 hours per day by Peper and Gibney [37]; 3.2 hours per day by Menendez et al. [33]). By contrast the undergraduate students in the current study reported closer to a daily average of 3.8 hours, and the graduate students a daily average of 4.8 hours, based on total weekly computer use. In the previous studies [33,37], the research focused on undergraduate students in upper level classes, and only asked about general daily computer use and not weekend/weekday computer use, as the current study has addressed. Inquiring about computing hours on specific days allowed for comparisons of computing hours on weekdays and weekends. On average, college students in the current study worked more on the computer during the weekdays than the weekends. During the weekdays, the daily average of computing was reported as 5.1 hrs for graduate students and 4.1 for undergraduate students. On the weekends, the hours were lower, with an average of 3.8 computing hours for graduate students and 3.1 for undergraduate students. Also notable was that graduate students were not included in the previous research [19,20,33, 37,49], though in the current study class standing was found to be significant, with graduate students reporting more computing hours than undergraduates. In a study focused solely on graduate students, Schlossberg et al. [40] found that computing hours increased with year in graduate school; 56% of participants reported greater than 40 hours per week by the end of their graduate studies. The only other study to include graduate students was a focus group study by Cortés et al. [11] which was qualitative research. In that study the research involved only symptomatic students, and it was a small sample of students, only seven undergraduates and nine graduate students.

Reported hours of use may not be a good estimate of actual computing hours. Several studies have demonstrated that both working adults and students tend to over-estimate their computer use time [4,17, 43]. Bernard et al. [4] found newspaper workers with hand symptoms reported 4.5 (s.d. 2.6) hours of use, while observed typing hours were 2.5 (s.d. 1.4), an overestimate of 80%. Their referent group overestimated their use by 100%. In Menendez et al. [33], college students reported 3.3 hours of daily computer use, while the observed hours were 2.7 per day, or 22% over reporting. Daily computer use can be variable for many users (those who are not performing routine tasks, such as data entry), making it difficult to provide a valid, accurate estimate of average daily use [44]. The current study allowed participants to provide average daily use or use per specific day, and, as such, the estimates of computer usage could, potentially, be more accurate and therefore the reported computing hours in the current study may not be as inflated.

Another question in the current study referred to the likelihood of using a computer during specific periods of time. As a group, the professional workers reported that they were at least *Somewhat likely* to use a computer between 6:00 am and 6:00 pm. As a group, the college students reported a pattern of computer use over a greater range of times throughout the 24-hour day, reporting being at least *Somewhat likely* to use the computer between 8:00 am and 2:00 am. Under any category of use certainty (except *Not likely*), college students indicate more 2-hour usage periods than the professional workers. This would tend to indicate that college students spread out their computer use over the 24-hour day, whereas professional workers concentrate their computer use into fewer hours. At this point, it is not obvious whether one pattern would be more or less harmful than the other. This would require further study.

The participants also provided information as to how likely they were to sit continuously using the computer for X amount of time before taking a break, with increments of 30, 60, 90, 120 minutes. The combined response for this set of questions was given the variable name PCSITSCR. A significant difference was found for Class, with graduate students' scores indicating longer and/or more frequent periods of continuous time sitting at a computer than the undergraduates. Other studies [33,37] inquired about break patterns similar to the current study's inquiry on time periods before breaks. However, Peper and Gibney [37] did not quantify the time allocations; only the act of a break, and the researchers deemed these to be alleviations of discomfort or pain rather than a common practice of healthy computing. In Menendez et al. [33], the students reported an average of 3.2 hours of daily computing, interrupted by only an average of 1.4 breaks; total estimated daily break time was 14.5 minutes. Katz et al. [26] attributed differences in the number of reported computing hours within different academic concentrations to a workstyle effect. For example, 'binge' computing would be more common within computer science than in history. This could also be true of graduate students meeting proposal/defense deadlines. From the current study, the PCSITSCR for college students was 3.8 (s.d. 0.7) and for the professional workers, 3.2 (s.d. 0.8). This indicates that the CS are working for longer periods of time and/or are more frequently working for uninterrupted periods than the PW. Galinsky et al. [12] studied the incorporation of a five minute rest break every hour, in addition to the conventional two–15 min breaks during the day, and found significantly lower discomfort and no decrement in performance. Through an education program, the importance of breaks may be further realized, and discomfort, associated with computer use, possibly reduced.

Within college students, the correlation between frequent discomfort and the composite score of time sitting in front of a computer before a break was 0.35. The correlation for college students and professional workers under 35 was similar at 0.39. This was consistent with Sommerich's [42] research showing a correlation of 0.31 found in the larger data set of the professional worker study. This continues to reinforce the need for education for computer users to take adequate rest breaks, as increased rest breaks reduce discomfort [12].

4.3. Strengths and limitations of this study

There are several limitations to the current work that should be noted. There was a low response rate, with less than 50% of the solicited college students completing the survey. Those college students that did not respond could not be contacted and therefore there is no assessment of the differences between respondents and non-respondents. Those that responded could easily have been students drawn to the nature of the study or more apt to volunteer for research; each are potential biases. In a few other studies a verification of the responses has been completed, such as comparisons of reported computing hours to actual observed computing hours; this was not done in the current study. The study also did not specifically investigate non-school-related use of computers; social networking and gaming add significantly to some students' computer exposure.

This study included a more diverse population than previous studies. Both graduate and undergraduate students were included. Forty percent of the students were graduate students. The students of two academic concentrations were included, humanities and social science (47%) and engineering (53%). Both males and females were well represented, with 63% of the students sampled being female. Also, efforts were taken to control for duplicate responses to the survey. Each student was given a separate ID code, and those responses that had identical ID codes or no ID code were not included in the analysis.

If this study is considered as a pilot effort, suggested improvements in methods include performing a more detailed analysis over a longer period of time, similar to the professional worker study [42]. Along with the longer study time, following up to compare actual versus reported values for use patterns, where possible, would improve the validity of the research. Including physical examinations or a detailed clinical assessment of those with symptoms could help further define the scope of the college students' risk of MSDs.

4.4. Suggestions for future work

Following a group of college students throughout their academic career would be a next step. College students could be medically evaluated and followed over time. Research into this younger population could further investigate the natural history of MSDs, because people now begin using computers at such an early age. Further, professional workers are developing their computing habits at younger ages, in college or earlier.

Another progression would be to gather more detailed information on work patterns. Further defined work patterns could yield ideas for interventions, directed at the college population, that would attempt to accommodate the user of a variety of computers, at various locations, during late hours, and all the other components that could place college students at risk for developing MSDs. Also, the comparison could be made over time, to determine if computer use plateaus among college students or increases, by comparing the two different time periods of studies.

Variations on these suggestions could include some students receiving one intervention technique over another. This could determine the types of programs that show effectiveness in a college setting. Studies involving younger college students and younger professional workers, those with and without symptoms, may aid in identifying effective interventions in colleges and universities, and other educational systems as well.

5. Conclusions

Efforts to reduce exposures to risk factors associated with MSD should not only include the workforce, but those that are beginning to use computers, including children in elementary school, middle school, and high school. College students are adults, and therefore are not a special population when compared to a developing child. However, proper workstation set-up and healthy computing are not yet common place terms in educational environments. For example, students at one university must proceed through two links on the student health services' website, which eventually links to a search engine's general health website, then two more links on this website before receiving any recommendations about healthy computing. On each website there is no clear direct path to healthy computing, so the student may become frustrated before finding the advice. As seen in other studies, health care professionals may not have much more to offer than 'limit computer use' as a primary suggestion to college students [11].

There remains a low level of awareness regarding risk of MSD development in college students, associated with computer use. This research was designed to show that risk factors previously identified in groups of professional workers, are also prevalent in the college students' environment.

The most important findings are the similarities and contrasts between college students and professional workers. As college students continue into advanced degrees and become graduate students, the amount of computer use on a weekly basis is very similar to the professional workers. College students reported a higher frequency of UE and neck discomfort than professional workers. Also, college students reported using computers from early in the morning until late in the evening, much later than the professional workers. This reduced recovery time for the college students may contribute to the higher frequency of discomfort.

Since Major was not found to significantly affect any of the variables in this study, these results imply that the issue of computer-related MSDs in college students should be addressed at the university level. Without some intervention, college students are more likely to enter the workforce with poor computing habits and MSD. With some information on computer ergonomics, a college student would know how to set-up his/her own computer workstation, and appreciate the potential risks of using poorly designed stations for long periods of time. Students who experience symptoms would know to seek attention for them before they progress to a permanent problem. The only known defenses to MSD are prevention or intervention. Knowledge and proper equipment are two factors that could help reduce a future workforce's risk of developing MSDs as a consequence of using computers.

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