Daily Computer Usage Correlated With Undergraduate Students' Musculoskeletal Symptoms

Che-hsu (Joe) Chang, PT, MS,[1] Benjamin C. Amick III, PhD,[2,3] Cammie Chaumont Menendez, MPH, MS,[2] Jeffrey N. Katz, MD, MS,[1,4] Peter W. Johnson, PhD,[5] Michelle Robertson, PhD, CPE,[6] and Jack Tigh Dennerlein, PhD[1]*

Background *A pilot prospective study was performed to examine the relationships between daily computer usage time and musculoskeletal symptoms on undergraduate students.*
Methods *For three separate 1-week study periods distributed over a semester, 27 students reported body part-specific musculoskeletal symptoms three to five times daily. Daily computer usage time for the 24-hr period preceding each symptom report was calculated from computer input device activities measured directly by software loaded on each participant's primary computer. General Estimating Equation models tested the relationships between daily computer usage and symptom reporting.*
Results *Daily computer usage longer than 3 hr was significantly associated with an odds ratio 1.50 (1.01–2.25) of reporting symptoms. Odds of reporting symptoms also increased with quartiles of daily exposure.*
Conclusions *These data suggest a potential dose–response relationship between daily computer usage time and musculoskeletal symptoms.* Am. J. Ind. Med. 50:481–488, 2007.
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KEY WORDS: musculoskeletal disorders; computer; upper extremity; exposure assessment; dose-response

INTRODUCTION

In the student population, several cross-sectional studies have reported high prevalence (41–81%) of self-reported upper extremity musculoskeletal disorders (MSDs) among senior undergraduate students, engineering graduate students, and female undergraduate students [Katz et al., 2000; Schlossberg et al., 2004; Hamilton et al., 2005]. These symptoms can be severe enough to limit university students' daily and school activities [Katz et al., 2002; Hupert et al., 2004], and further result in disabilities that affect this next generation of workers' career and health.

Prolonged self-reported computer usage is the most consistently reported risk factor for computing-related MSDs across study populations [Gerr et al., 2004]. Among the student population, self-reported weekly

[1]Department of Environmental Health, Harvard School of Public Health, Boston, Massachusetts
[2]The University of Texas School of Public Health, Houston, Texas
[3]Institute for Work and Health, Toronto, Canada
[4]Department of Orthopaedic Surgery and Divison or Rheumatology, Immunology and Allergy, Brigham and Women's Hospital, Boston, Massachusetts
[5]Department of Environmental and Occupational Health Science, School of Public Health & Community Medicine, University of Washington, Seattle, Washington
[6]Liberty Mutual Research Institute for Safety, Hopkinton, Massachusetts
This work was performed at The Harvard School of Public Health and The University of Texas Health Science Center at Houston.
Contract grant sponsor: National Institute for Occupational Safety and Health (NIOSH)/ Centers for Disease Control and Prevention (CDC); Contract grant number: R01OH03997 and T42CCT610417. Contract grant sponsor: The Office Ergonomics Research Committee.
*Correspondence to: Jack Tigh Dennerlein, Harvard School of Public Health, 665 Huntington Avenues, Boston, MA 02115. E-mail: jax@hsph.harvard.edu

Accepted 22 February 2007
DOI 10.1002/ajim.20461. Published online in Wiley InterScience (www.interscience.wiley.com)

computer usage longer than 20 hr has been associated with musculoskeletal symptoms [Katz et al., 2000; Schlossberg et al., 2004]. In previous cross-sectional studies, duration of computer usage was, however, assessed with self-reports, and the measurement inaccuracy might result in exposure misclassification [Homan and Armstrong, 2003]. Further, only the relationship between long-term exposure (e.g., years computing, average computing hours in the last few weeks) and long-term outcome (e.g., experience of computing-related symptom, persistent or recurrent pain) were tested due to the limitation of cross-sectional study design [Katz et al., 2000; Schlossberg et al., 2004]. Since musculoskeletal symptoms can vary within the framework of a single day [Amick et al., 2003], short-term (e.g., daily) relationships between computer usage and musculoskeletal symptoms might also be possible. To test such hypothesized short-term relationships, however, accurate longitudinal exposure data of computer usage is needed.

Exposure duration of computer usage can be objectively quantified by using computer usage monitor software to directly measure computer input device activities (pointing device and keyboard activities). Computer usage monitor software is an unobtrusive and accurate exposure assessment tool [Chang et al., 2004], and it does not require the high cost or work associated with traditional direct measurement methods [Winkel and Mathiassen, 1994]. Furthermore, with the longitudinal and continuous data collected by computer usage monitor software, exposure within short windows can be accurately calculated to examine the short-term dose–response relationship between computer usage and MSDs.

In addition to computer usage duration, gender has also been associated with MSD prevalence. For example, computing-related upper extremity MSDs are more prevalent among females in both working population and student population [Punnett and Bergqvist, 1999; Katz et al., 2000; Gerr et al., 2002]. While gender differences could diminish when physical exposures are controlled [Punnett and Bergqvist, 1999], laboratory studies consistently demonstrate gender differences in physical exposure to posture and force load [Martin et al., 1996; De Smet et al., 1998; Karlqvist et al., 1998; Wahlstrom et al., 2000]. Although gender differences have been reported, the effect of genders in the relationship between computer usage and MSDs remains unclear.

The goals of this pilot study are to characterize directly measured computer input device usage patterns and to examine the relationships between daily computer usage time and daily musculoskeletal symptoms in a cohort of 27 undergraduate students. This study tests the hypothesis that longer daily computer usage time is associated with higher odds of reporting musculoskeletal symptoms. In addition, gender differences in exposure, symptom reporting rates and the potential dose–response relationships are also explored.

METHODS

Participants

We measured self-reported musculoskeletal symptoms and computer input device usage in a cohort of 27 undergraduate students (13 males and 14 females, 20.6 ± 1.5 years old) over three 1-week periods during (at the beginning, the middle, and the end of) their spring semester. These participants were a subset of a convenience sample of 30 students from a single university dormitory [Menedez et al., in press]. Ninety percent (90%) of the participants' primary computers were desktop computers. The study protocols were approved by the human subject protection review boards of the authors' and the participants' institutions. All participants were required to provide informed consent prior to participating in the study.

Measuring Daily Musculoskeletal Symptoms

To measure musculoskeletal symptoms, each participant completed a questionnaire implemented on a personal digital assistant (PDA) multiple times a day during the three 1-week study periods. The PDA was carried with each participant, randomly prompted the participants with audible alarms 10 times a day, and the participants completed the questionnaire if they were available at the time of the prompt. When a questionnaire was completed, the completion time was also recorded by the PDA. We obtained an average of four PDA measurements (i.e., symptom reports) per participant per day throughout the study period. The PDA questionnaire used five-level scales (none, mild, moderate, severe, and very severe) to assess current pain and discomfort severity for 13 body parts (neck, upper back, lower back, left/right shoulder, left/right upper arm, left/right forearm, left/right wrist, and left/right finger). Prevalence of self-reported musculoskeletal symptoms was calculated for descriptive purposes.

Measuring and Characterizing Daily Computer Usage Time

Custom-designed computer usage monitor software was installed onto each participant's primary computer.

The program collected computer usage time data for the three 1-week study periods only. To be included in the study, participants had to report using their primary computers, which were monitored by our software, at least 80% of their computing time (3 of the original convenience sample did not meet this criterion reducing the cohort to 27). The usage monitor program was developed on Labview platform (National Instruments Co., Austin, TX) and compatible with Microsoft Windows® operating systems. Input device activities (i.e., keystrokes, cursor movements driven by the pointing device and pointing device button activations) were recorded continuously by the usage monitor software during the study periods. The temporal duration of each discrete input device activity was recorded with the accuracy of two milliseconds [Chang et al., 2004]. To maintain the participants' privacy, the specific letters typed on the keyboards were not recorded.

Throughout the three 1-week study periods, each participant's computer input device usage pattern was characterized as average daily computer usage (including both pointing device and keyboard usage) time, average daily pointing device usage time, and average daily keyboard usage time. We calculated the average daily computer usage time for each participant by first summing all pointing device and keyboard activity time recorded by the software along with all inactivity periods of 60 s or shorter. The sum was then divided by the number of observational days for the average daily usage time. The inclusion of the short inactivity periods ($\leq$60 s) captured the user's passive interaction with the computer, such as viewing monitor or users' hands transferring between the pointing device and the keyboard [Chemor-Ruiz et al., 2003]. We also calculated the average daily pointing device usage time and average daily keyboard time by only including either pointing device activity or keyboard activity into the usage time calculation. For each participant, the ratio of average daily pointing device usage time to keyboard usage time was calculated to describe the input device usage pattern.

Statistical Analysis

To test the hypothesis that musculoskeletal symptoms are related to daily computer usage, we defined the outcome to be the dichotomous measure of musculoskeletal symptoms and calculated the associated exposure as the preceding 24-hr (daily) computer usage time for each symptom report. Each PDA symptom report represented a data point in the statistical analysis. The outcome of a symptom report (i.e., a data point) was dichotomized and defined as "symptomatic" if the symptom severity of at least one body part was moderate, severe, or very severe. Otherwise, the outcome of a data point was defined as "asymptomatic". Based on the questionnaire completion time of each PDA symptom report, we calculated the exposure as the software-recorded computer usage time for the 24-hr (daily) period prior to the time the questionnaire was completed. The computer usage time was calculated by the same method described above for characterizing usage pattern. The 24-hr exposure window was chosen to examine the short-term effect of exposure and to include equal duration of daytime and night-time exposure windows.

We tested the relationship between the musculoskeletal symptom outcome (symptomatic/asymptomatic) and seven sets of daily exposure metrics, including five dichotomous exposure variables, one categorical exposure variable and one continuous variable. The five dichotomous exposures variables (i.e., high/low) were created using different thresholds of 2, 2.5, 3, 3.5, and 4 hr of daily computer usage time respectively. The categorical exposure variable was created by categorizing the daily computer usage time with the quartiles across all data points (1st, 2nd, 3rd, and 4th quartile). Each created exposure variable was tested separately for its relationship with the musculoskeletal symptoms.

General Estimating Equation models (GEE) (SAS 9.0, Cary, NC) were used to test the hypothesis that longer daily computer usage time is related to higher odds of reporting musculoskeletal symptoms. In the statistical models, the dichotomous musculoskeletal symptom outcome (symptomatic/asymptomatic) was the dependent variable, the preceding daily computer usage time was the fixed effect independent variable, and the subject was modeled as a random effect independent variable. Exposure of daily computer usage time was treated as continuous, dichotomous, and categorical as described above, and tested in separated models. *P*-values or 95% confidence intervals were used to describe statistical significance. Statistical significance level was set to be 0.05 and adjusted to (0.05/n) for models that had n pairs of comparisons. For the dichotomous and categorical exposure variables, the lowest exposure level was the reference with which all other levels were compared.

To further explore the relationship between daily computer usage and daily musculoskeletal symptoms, we also compared the daily computer usage time across different symptom severities. Analogous to a case crossover study where the exposure of cases and that of controls is compared in self-matched analysis, we implemented a GEE model with the preceding daily computer usage time set as the dependent variable, and symptom severity and subject were set as the independent variables. The level of "very severe" was combined into "severe" due to the small sample size (19 reports, 0.9% of all self-reports). The level of "no symptom" was the reference with which all other levels were compared.

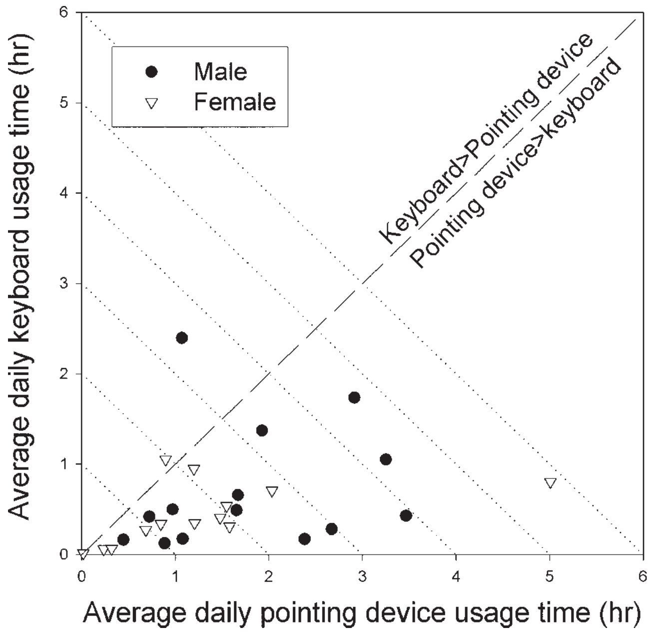

FIGURE 1. Average daily pointing device usage time versus keyboard usage time for the 27 participants throughout the study periods. The dash line represents one-to-one relationship. The dotted lines (left-top to right bottom) denote hour increments of daily computer usage time.

To examine gender differences, males and females' symptom reporting rates (symptomatic report/day) and average daily compare usage time were compared by two-sample t-tests. All GEE models described above were also further stratified by gender to examine potential gender differences.

RESULTS

Musculoskeletal Symptoms

During the entire study period, 96% of the participants reported musculoskeletal symptoms of any severity at least once; 81% of the participants reported moderate or greater symptoms at least once. The most prevalent symptomatic body parts were neck (48% of the participants reported moderate or higher neck symptom at least once), lower back (44%), upper back (40%), and shoulders (37%).

Daily Computer Usage Time

The average daily computer usage for the first, second and third observational periods during the semester were 2.2 (SD 1.8) hr, 3.1 (SD 2.8) hr, and 1.8 (SD 1.5) hr, respectively. Average daily pointing device usage time (1.6 ± SD 1.1 hr) was significantly ($P < 0.01$) longer than average daily keyboard usage time (0.6 hr ± SD 0.6 hr) across all participants across all three observational periods (Fig. 1). Twenty-four (24) of the 27 participants (89%) spent more time using the pointing device than using the keyboard. Combining pointing device and keyboard usage resulted in average daily computer usage ranging from 0.2 to 5.6 hr across participants (mean 2.1 hr, SD 1.4 hr). The ratios of pointing device usage time to keyboard usage time varied from 0.4 to 14.1 across participants (mean 4.6, SD 3.9).

Relationship Between Daily Computer Usage and Daily Symptoms

When the duration of daily computer usage was dichotomized by 3 hr, daily computer usage time greater than 3 hr was related to 50% significantly higher odds (odds ratio = 1.50, 95%CI = 1.01–2.25) of reporting musculoskeletal symptoms (Table I). The 3.5-hr dichotomization threshold also exhibited a similar relationship with 51% significantly higher odds of reporting symptoms for the high exposure level. Dichotomizing the exposure with 2 hr, 2.5 hr, or 4 hr did not demonstrate statistical significance in the results. The odds of reporting symptoms also consistently increased from the first quartile to the fourth quartile of exposure (OR = 1.95, 95%CI = 0.77–4.93 at the 4th quartile, Table II) but without statistical significance. When the exposure was treated as a continuous independent variable, every hour increase of daily computer usage marginally increased the odds of reporting symptoms by 5%

TABLE I. Odds Ratios (OR) of Reporting Musculoskeletal Symptoms for Different Dichotomous Daily Exposure Variables

		Complete cohort (N = 27)		Male (N = 13)		Female (N = 14)	
Low exposure	**High exposure**	**% of high exp.**	**OR (95% CI)**	**% of high exp.**	**OR (95% CI)**	**% of high exp.**	**OR (95% CI)**
≤2.0 hr	>2.0 hr	46%	1.43 (0.92–2.24)	46%	2.01 (0.91–4.44)	45%	1.23 (0.72–2.10)
≤2.5 hr	>2.5 hr	38%	1.44 (0.98–2.09)	**39%**	**1.96*(1.12–3.42)**	38%	1.25 (0.78–1.98)
≤3.0 hr	>3.0 hr	**32%**	**1.50*(1.01–2.25)**	**34%**	**2.09*(1.17–3.72)**	30%	1.29 (0.76–2.20)
≤3.5 hr	>3.5 hr	**27%**	**1.51*(1.01–2.25)**	**28%**	**1.88*(1.16–3.05)**	27%	1.36 (0.78–2.34)
≤4.0 hr	>4.0 hr	23%	1.28 (0.85–1.93)	23%	1.64 (0.93–2.89)	23%	1.13 (0.65–1.98)

Bolded and starred * values indicate $P < 0.05$.

TABLE II. Odds Ratios of Reporting Musculoskeletal Symptoms for the Categorical Daily Exposure Variable

	Complete Cohort (N = 27)		Male (N = 13)		Female (N = 14)	
Exposure quartile	Daily usage time (hr)	OR (95% CI)	Daily usage time (hr)	OR (95% CI)	Daily usage time (hr)	OR (95% CI)
1st	0.0–0.3	—	0.0–0.6	—	0.0	—
2nd	0.3–1.7	1.49 (0.77–2.89)	0.6–1.9	2.18 (0.44–11.06)	0.1–1.6	1.51 (0.72–3.17)
3rd	1.7–3.7	1.50 (0.70–3.24)	1.9–3.7	3.22 (0.83–12.44)	1.6–3.7	1.28 (0.51–3.22)
4th	>3.7	1.95 (0.77–4.93)	**>3.7**	**4.12*(1.21–14.00)**	>3.7	1.62 (0.53–4.96)

The exposure was categorized by the quartiles of daily computer usage time across all data points within each gender.
Bolded and starred* values indicate $P < 0.05$.

($P = 0.1$). Daily computer usage times preceding different symptom severity levels were not statistically different across the four levels (Fig. 2).

Differences Between Genders

Throughout the study period, females' symptom reporting rates were marginally higher than males' (0.8 ± 1.0 symptom/day vs. 0.2 ± 0.2 symptom/day, $P = 0.052$). Average daily computer usage time was not statistically different between males and females (2.5 ± 1.3 hr vs. 1.7 ± 1.4 hr, $P = 0.13$).

In the gender-stratified GEE models, longer daily computer usage was also associated with higher odds of reporting daily symptoms in a pattern similar to the whole cohort, but statistical significance was found only among males. The smallest sample size for any cell in the gender-stratified analysis was four, and most of the cells had sample size of six or greater. When the exposure was dichotomized by 2.5, 3, or 3.5 hr of daily computer usage, males demonstrated that high exposure level was significantly related to higher odds of reporting musculoskeletal symptoms (Table I). Males' odds ratios of reporting symptoms also consistently increased from the first quartile to the fourth quartile of daily computer usage time, which achieved statistical significance (Table II). Among females, although high exposure was always related to higher odds of reporting symptoms when compared with the first exposure quartile, the relationship was not statistically significant. The continuous exposure variable also exhibited statistically significant relationship with musculoskeletal symptoms among males but not females. For males, every hour increase of daily computer usage was associated with 18% higher odds ($P < 0.05$) of reporting daily symptoms.

Among males, exposure of preceding daily computer usage increased from no symptom (2.4 hr) to mild symptoms (2.6 hr) to moderate symptoms (4.2 hr, $P < 0.05$ when compared with no symptom); and the daily computer usage time then decreased to 2.3 hr at severe symptoms (Fig. 2). Among females, no trend of exposure across symptom severities was observed.

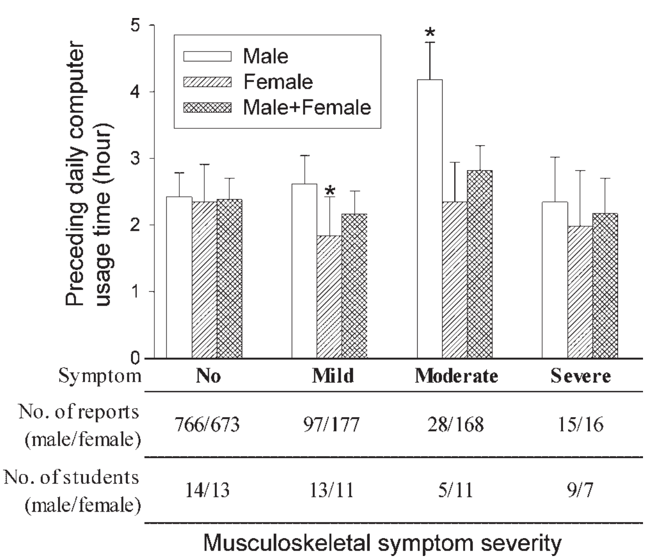

FIGURE 2. Least square means for daily computer usage time preceding each different symptom severity level. Error bars are the standard errors for least square means. * denotes $P < 0.05$ when compared with "No symptom".

DISCUSSION

The aims of this pilot study were to investigate the relationships between daily computer usage time and daily musculoskeletal symptoms and to characterize computer input device usage patterns in a cohort of 27 undergraduate students. Our results indicated that longer daily computer usage was associated with higher odds of reporting musculoskeletal symptoms, and also suggested a potential dose-response relationship. The observed relationship was, however, different between genders.

While previous cross-sectional studies examined the relationship between long-term exposure and long-term outcome [Katz et al., 2000; Schlossberg et al., 2004], our results suggested a potential short-term effect of daily computer usage. High daily exposure was related to higher odds of reporting daily symptoms with short latency (within 24 hr).

Three (3) and 3.5 hr of daily usage related to increased odds of reporting symptoms could translate to roughly 20 hr of weekly usage, which is comparable to the self-reported 20-hr weekly usage identified by previous studies [Bergqvist et al., 1995; Katz et al., 2000; Schlossberg et al., 2004]. In addition to the validity difference [Homan and Armstrong, 2003], the methodological differences between self-reported and directly measured computer usage should be noted when interpreting the results. First, in our direct measure, computer usage was only recorded from one primary computer for each participant. Although all participants reported using their primary computers at least 80% of their computing time, usage on other computers was not measured. Second, while self-reported computer usage were based on subjective judgment of overall computing activities, our estimate was based on the assumptions that directly measured input device activities could account for passive interaction. The users' passive interaction with computer (e.g., viewing the monitor) was estimated by including all input device inactivity periods shorter than 60 s into the estimate. This threshold was based on our preliminary data demonstrating the 60-s threshold can accurately estimate video-taped actual computer usage with an average estimate error of 5% across 10 office workers. This threshold will be further verified elsewhere.

A potential dose–response relationship was suggested since the sensitivity analysis (the categorical exposure metric) indicated the odds of reporting daily symptoms consistently increased as daily computer usage time increased. Although the result of the sensitivity analysis was not statistically significant for the whole cohort, the relationship became significant among males when the analysis was stratified by gender. Limited by the small sample size, the observed gender difference could not be tested with sufficient statistical power.

The observed gender difference might result from the small sample size of this pilot study and females' higher prevalence of more severe, more frequent and longer general musculoskeletal pains [Unruh, 1996]. The females in our study cohort reported symptoms more frequently than the males. If our musculoskeletal symptom measure captured females' symptoms irrelevant to computer usage, we might have included more outcome variability that was not associated with the exposure. The combination of higher outcome variability and small sample size limited our statistical power to detect females' exposure–outcome relationship.

Additionally, combining all the body parts together in our data analysis might result in outcome misclassification. We combined all the body parts to obtain a larger sample size for higher statistical power. To rule out the aforementioned outcome misclassification, we also stratified the analyses by body parts, and most prevalent body parts exhibited exposure–outcome relationships similar to what was observed on the combined symptoms. Although statistical significance was not observed due to the small sample size of the body-part-stratified models, the similar patterns suggested combining body parts together is unlikely to result in biasing outcome misclassifications.

The results also indicated that severe musculoskeletal symptoms were associated with decreased daily computer usage time. The decreased computer usage might result from functional limitation or the computer users' self-adjustment to prevent symptom exacerbation. To further support this potential explanation, we also examined the relationship between the symptoms and the daily computer usage time following the symptoms. A similar trend was observed where severe symptoms have shorter following daily computer usage time than any other symptom severities. Although a potential negative feedback from the outcome to the exposure was suggested by the results, data on functional limitation is needed to examine the underlying relationship and mechanism.

Our analysis did not control for other potential MSD risk factors, such as anthropometric dimensions, users' postures, and other transient risk factors of musculoskeletal symptoms. The repeated measures design of this study prevented possible biases resulting from individual risk factors that do not change in a short period of time (e.g., anthropometric dimension). Working posture has been related to MSD's of upper extremities, neck, upper back and carpal tunnel syndrome [Faucett and Rempel, 1994; Bergqvist et al., 1995; Matias et al., 1998; Marcus et al., 2002]. In our study design, using daily computer usage time as the estimate of exposure is, however, based on the assumption that the type of exposure remains consistent (e.g., small or no change of posture) throughout the time. Although within-subject postural change could be sufficiently stable over time [Ortiz et al., 1997], our assumption needs to be further verified. Other potential transient risk factors, such as physical activities or practicing musical instruments, were unlikely to be related to daily computer usage time. Even if these transient risk factors were correlated with daily computing time, a negative correlation would be more plausible (e.g., longer computing time correlated with shorter exercise time) and therefore might have biased our results towards the null. Accordingly, we might expect the underlying relationship between daily computer usage and daily musculoskeletal symptoms to be stronger than what was observed.

The primary limitations of this pilot study are the small sample size and the short observational period. First, the small sample size limited the generalizability of our results and prevented us from testing other factors that might contribute to the exposure–outcome relationship. For example, the widely varied ratios of pointing device to keyboard usage time (0.4–14.1, corresponding to a 35-fold range) suggested the type of physical exposure varied greatly across the individuals in this cohort. Pointing device use and keyboard use are related to different physical loading on different body parts: mouse usage was related to more non-neutral postures and higher neck muscle activities when compared with keyboard usage [Laursen et al., 2002; Dennerlein and Johnson, 2006]. Given our sample size, we were unable to examine the different effects between pointing device usage and keyboard usage on individual body parts.

The 1-week consecutive observational period made it difficult for us to examine exposure windows longer than 24 hr. While the exposure window in this study was 24 hr, computer usage earlier than 24 hr might also be related to musculoskeletal symptoms, in which case we would not observe a dose–response relationship among females. Our data were collected consecutively for only 5–7 days for each separate study week. Extending the exposure window beyond 24 hr would reduce the number of data points since the data points of the first few days in each study week would have incomplete exposure history.

Despite the limitations, the strength of our study was using objective quantitative exposure assessment (i.e., computer usage monitor software) and PDA questionnaire to collect longitudinal exposure and outcome data. The direct measure of exposure prevented potential exposure misclassifications; and the longitudinal data enabled us to test the daily dose–response relationship with a repeated measures study design.

In conclusion, we demonstrated that longer daily computer usage time was related to higher odds of reporting daily musculoskeletal symptoms; and we characterized a wide variety of computer input device usage patterns in this cohort of undergraduate students. The observed high musculoskeletal symptom prevalence and the potential relationship between computer usage and symptoms suggested that further research is needed to protect the student population. A potential daily dose–response relationship was also observed among the males in the cohort. The small sample size and the short study period limited us to further investigate the observed gender differences and other potential MSD risk factors. Longer study period, larger study cohort, and collecting data on functional limitations, postures, and transient risk factors are therefore suggested for future studies.

ACKNOWLEDGMENTS

This work was partly supported by National Institute for Occupational Safety and Health (NIOSH)/Centers for Disease Control and Prevention (CDC) Grant (1R01 OH03997-01) at Harvard University, another NIOSH/CDC grant at the University of Texas School of Public Health (T42CCT610417) and the Office Ergonomics Research Committee. Cammie Chaumont Menendez was supported by an Occupational Injury Prevention Training Grant (T420H008421) from NIOSH/CDC. The authors would also like to acknowledge Miss Jenn Ibbotson for her assistance in the software programming and data analysis, and Dr. Ellen Eisen for her consultation in statistical analysis.

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