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University students' notebook computer use

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ABSTRACT

Recent evidence suggests that university students are self-reporting experiencing musculoskeletal discomfort with computer use similar to levels reported by adult workers. The objective of this study was to determine how university students use notebook computers and to determine what ergonomic strategies might be effective in reducing self-reported musculoskeletal discomfort in this population. Two hundred and eighty-nine university students randomly assigned to one of three towers by the university's Office of Housing participated in this study. The results of this investigation showed a significant reduction in self-reported notebook computer-related discomfort from pre- and post-survey in participants who received notebook computer accessories and in those who received accessories and participatory ergonomics training. A significant increase in post-survey rest breaks was seen. There was a significant correlation between self-reported computer usage and the amount measured using computer usage software (odometer). More research is needed however to determine the most effective ergonomics intervention for university students.

1. Introduction

There are a limited number of systematic studies that have examined university students' use of computers (Katz et al., 2000; Crook and Barrowcliff, 2001; Cortes et al., 2002; Robertson et al., 2002; Hupert et al., 2004; Hamilton et al., 2005; Fay, 2006; Menendez et al., 2007; Jenkins et al., 2007). Several of these studies reported an association between university students' computer use and self-reported musculoskeletal discomfort (Katz et al., 2000; Cortes et al., 2002; Robertson et al., 2002; Hupert et al., 2004; Hamilton et al., 2005; Menendez et al., 2007; Jenkins et al., 2007). One of these studies (Robertson et al., 2002) attempted to address this association, and implemented a participatory ergonomics approach to the process of developing a computer ergonomics training workshop for university students. Results suggested that by using a participatory approach that incorporated an instructional systems design process with active adult learning and inquiry into a computer ergonomics workshop, students were able to increase their knowledge of computer ergonomics and were able to apply this knowledge to solve computer workstation problems (Robertson et al., 2002). Participatory ergonomics is, "The involvement of people in planning and controlling a significant amount of their work activities, with sufficient knowledge and power to influence both processes and outcomes in order to achieve desirable goals" (Wilson and Haines, 1997, pp. 490–513). Although a participatory ergonomics approach has been used effectively in industry, Robertson et al's study is one of the first to report its successful use with university students.

Notebook computers account for 25% of the computer market (Consumers Union of US, Inc., 2005–2008) and sales are projected to increase 28% over the next year (Daoud and Bell, 2007). Notebook computer use by university students has increased from 52.8% in 2005 to 75.8% in 2007 (Salaway and Caruso, 2007), but despite this growth in popularity, there is a scarcity of studies that specifically investigate notebook computer use in this population (Fay, 2006). Since a majority of today's students may work in office

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environments in a few years, it is therefore important to understand university students' notebook computer use, and to design ergonomic strategies for this population that are effective in preventing or reducing self-reported musculoskeletal discomfort. Additionally, since these students spend the majority of their notebook computer usage time at "home" in their dormitories (Fay, 2006), it is ecologically desirable to conduct studies of notebook computer use in the dormitory setting. It is also vital to investigate the ergonomics strategies involved in the student population as "the ergonomic design of the learning environment influences learning performance" (Smith, 2007, p. 1532).

The purpose of this study is to investigate how university students use notebook computers and to determine what ergonomic strategies such as promoting students to find their comfort zone and to safely arrange and adjust their notebook computer work areas might be effective in reducing self-reported musculoskeletal discomfort in this population.

2. Methods

2.1. Study participants

Two hundred and eighty-nine undergraduate students (39% males; 61% females) were recruited in spring 2007 from a single college dormitory at a private university in the New England area of the United States. Only students using notebook computers were invited to participate in the study. Because of the notebook restriction and attrition, 223 undergraduates participated for the full duration of the study. Institutional Review Board approval was obtained from the university.

2.2. Study design

A repeated measures study design was used. The duration of the study was three months from pre- to post-surveys. At baseline, all participants completed an ergonomics quiz and the College Computing and Health Survey. Anthropometric measurements were taken to ensure that participants in all of the conditions were comparable in body size. Participants were photographed in their dormitory room while using their notebook computers in non-poised postures. In addition, computer usage software (Tools for exposure assessment of physical risk factors of VDT Workers (NIOSH 2 R01 OH003997, PI: Jack Dennerlein)) was installed on each participant's notebook computer which measured time using computer; time using keyboard; time using mouse; time of first use; time of last computer use, number of keystrokes for each key and total number of keystrokes; number of mouse clicks; number of mouse movements; the number of micropauses and breaks; work–rest profile and patterns of usage.

The dormitory is structurally divided into three towers and participants were randomly assigned to one of these towers by the university's Office of Housing. To minimize the diffusion of experimental effects, each tower was randomly assigned to one of the three conditions – Tower A was assigned to the control condition, B to experimental condition #1, and C to experimental condition #2. Participants in the control condition completed the survey, quiz, and had the computer usage software installed on their notebook computer. Participants in experimental condition #1 received control conditions plus received external notebook accessories, e.g. an external keyboard, external mouse and notebook riser and had a second computer usage monitor software program installed that is capable of detecting external keyboard and mouse usage on their notebook computer. Participants in experimental condition #2 received conditions #1 plus 30 min of participatory ergonomics training and had a second computer monitoring software installed on their notebook computer. At the conclusion of the participatory ergonomic training, participants in condition #2 were asked to write a personal goal for promoting a safe and comfortable computer workstation environment. Over the duration of the study (three months) participants corresponded through monthly e-mail with the primary investigator to evaluate their goal, problem solve ways to facilitate progress towards the goal and, when necessary, reformulate the goal or set a new goal. For example, one participant wrote the goal to spend less time on the notebook computer for nonschool related activities. This participant reported using a timer to limit her daily nonschool use.

At the conclusion of the study, the participants returned their external notebook accessories.

2.3. Survey methods and instruments

There were two methods of data collection: self-report and direct measurement. Table 1 lists exposure data with corresponding survey instruments and method.

2.3.1. Self-report methods

There were two self-report methods used: 10-statement true/false ergonomics quiz and the College Computing and Health Survey. Both measures were paper-based and completed at pre- and post-study. On average, completion of the quiz was 3–5 min and the survey was 10–15 min.

The 10-statement true/false ergonomics quiz was composed of content from the participatory ergonomics training. Two examples of these true/false statements are:

- When typing on a notebook computer, your wrists, hands and forearms should be in their neutral comfort zone.
- You should rest your hands and wrists while typing or pointing.

The quiz was administered to participants prior to the participants' completion of the College Computing and Health Survey at pre- and post-study. The sum of all of the correct answers was calculated as the ergonomic score. The objective of the quiz was to ascertain the participant's knowledge and beliefs about ergonomics.

The College Computing and Health Survey was used to record demographic information and document physical change, behavioral change, and discomfort associated with computer usage. Discomfort was measured on a 5 point Likert scale from "I do not have this" to "very severe" by areas of the body. This survey has been used in studies of university students and was adapted to focus questions around the notebook rather than desktop computer (Katz et al., 2000: Amick et al., 2003; Hupert et al., 2004; Jenkins et al, 2007; Menendez et al., 2007). The survey has ten sections: common location of your notebook computing, hours per day spent using your notebook computer, portion of time using your notebook computer vs. your desktop computer, pain and discomfort due to computing, location of pain and discomfort, e.g. hands, wrists, arms, shoulders, low back or neck, sought treatment from a healthcare provider for this discomfort, severity, location, and duration of pain and discomfort in the past two weeks, discomfort

Table 1
Exposure data with corresponding survey instruments and methods.

Exposure	Self-report	Direct
Notebook computing patterns	College Computing & Health Survey	WorkPace© software
Computer usage software		
Musculoskeletal discomfort	College Computing & Health Survey	

experienced with numbness and tingling, overall health and school participation and demographic information.

2.3.2. Direct methods

Three types of direct measurement methods were used: the computer monitoring software installed on the participants' notebook computer that measured usage, anthropometric measurements of participants and photographs of participants' computer workstations.

WorkPace® software by Wellnomics® (New Zealand) was installed on all participants' notebook computers. It recorded exposure level factors, such as usage, and breaks. WorkPace® software was selected because it is compatible for use on both PC and Apple computers.

Anthropometric measurements such as seated eye height, seated elbow height and popliteal height were measured by research assistants to ensure that participants in all of the conditions are comparable in body size.

Photographs were taken of the participants at their computer workstations in their dormitory room at pre- and post-study by the research assistants.

2.3.3. Participatory ergonomic training

Participatory ergonomics training involved the participants in condition #2 in planning, developing, and implementing ergonomic solutions to a notebook computer workstation in a typical dormitory room (Greene et al., 2005). Content for the participatory ergonomics training was based on a variety of current evidence-based sources, such as the, ANSI/HFES 100-2007 Human Factors Engineering of Computer Workstations Standards, Hewlett-Packard Company's Safety & Comfort Guide (2002), and Healthy Computing Microsoft Hardware's Guide to Ergonomics at Work (2003). Participants were provided with a checklist on how to arrange their notebook computer workstation, instructed on how to use this checklist and given the opportunity to implement this knowledge. The checklist was created from the content included in the participatory ergonomics training. A focus was on the catchphrase: Work comfortably: change and vary your postures often. Each participant also received a mouse pad with this catchphrase and ergonomics information that included the key principles reinforced during participatory ergonomics training. For example, the following principles were discussed and participants had the opportunity to arrange a computer workstation to apply them: Use a separate keyboard and press the keys lightly; if you are sitting in a chair, keep your feet flat on the floor or use a foot rest; use a headset for mobile phone use; use an external mouse and keep it close to the separate keyboard; mouse and keyboard should be at elbow height, and to take rest breaks every 20 min. Multiple participatory ergonomics training sessions were provided so that the group sizes never exceed five participants. All training was provided by the primary researcher who is an occupational therapist and a Board Certified Professional Ergonomist (CPE).

2.4. Statistical analysis

All data was entered into Microsoft Office Excel 2007 and analyzed using SAS version 9.1 (copyright SAS Institute, Cary NC). Categorical data was summarized using percentages and analyzed using the chi-square test for independent samples and McNemar's test for paired designs. Numerical variables were summarized using means and standard deviations and analyzed using independent sample t-test and paired t-test as appropriate. Linear regression was conducted to test for trends between experimental groups. Pearson product-moment correlation was used to describe and test the strength of association between numerical variables.

Each test was two-sided and conducted at the 0.05 level of significance.

3. Results

3.1. Study population

Study population included 289 participants, 39% males and 61% females. Table 2 lists participants' characteristics at baseline. The participation rate is 16% based on 1800 residing in the dormitory.

3.2. Prevalence of self-report notebook computer-related discomfort and associations

At baseline, 66% of the participants self-reported notebook computer-related general discomfort in the College Computing and Health Survey. Before the study and at the end of the three-month intervention period there were significant changes in self-reported comfort reported by participants in condition #1 (78% versus 65%; $p = 0.008$) and condition #2 (61% versus 49%; $p = 0.007$) but no change in participants in the control condition (58% versus 55%, $p = 0.23$). The differences in self-reported discomfort reduction across the three conditions displayed a trend towards significance ($p = 0.24$).

Participants self-reported using the notebook computer and doing other activities at the same time. Table 3 lists these activities. Although it is interesting to understand that participants multitask while computing, there were no significant associations between these activities and self-reported discomfort ($p > 0.10$) in each condition.

There were no self-reported differences in typing proficiency. Participants self-reported touch-typing levels (typing without looking at the keyboard) as 78% (control $n = 78$), 83% (condition #1 $n = 84$) and 82% (condition #2 $n = 84$). There was a borderline relationship between self-reported notebook computer-related discomfort and touch-typing in experimental conditions #1 ($p = 0.067$) and the control group ($p = 0.083$) but not in condition #2 ($p = 0.855$).

3.3. Self-report notebook computer use characteristics

At pre-study, there was no significant difference between participants' self-report of taking regular short breaks when using the notebook computer and those who did not take a break in association with self-reported notebook computer-related discomfort. Chi-square test for this association was $p = 0.80$. At post-study there was a significant increase in the percentage of participants taking regular computer breaks from pre-study in condition #2 ($p = 0.002$). At post-study, participants self-reported taking regular computer breaks 74% (control $n = 78$), 86% (condition #1 $n = 84$) and 93% (condition #2 $n = 83$).

Fig. 1 lists the self-reported number of hours of notebook computer use.

Table 2
Participants characteristics: baseline survey results.

Characteristic	Control %(n)	Experimental condition #1 %(n)	Experimental condition #2 %(n)
Number of participants (n)	91	99	99
Average age (years)	19.7	19.4	19.3
Age range (years)	19–22	19–23	18–22
Females	53%	72%	57%
Males	47%	28%	43%
Ethnicity	66% Caucasian, 26% Asian	51% Caucasian, 33% Asian	68% Caucasian, 15% Asian

Table 3
Percentage of participants using notebook and doing other activities.

Condition	Use the phone	Listen to music	Watch TV	Other
Control ($N = 75$)	72%	99%	68%	9%
Experimental condition #1 ($N = 84$)	69%	95%	60%	11%
Experimental condition #2 ($N = 82$)	52%	93%	62%	15%

3.4. Direct measures of notebook computer use

Based on data retrieved from the WorkPace® software, participants across each condition spent 2.5 h daily using their notebook computers ($n = 237$). Their daily use of the mouse was 1.5 h ($n = 237$); daily use of keyboard was 32 min ($n = 233$); daily number of mouse clicks was 1.4k ($n = 237$); daily number of keystrokes was 5.1k ($n = 233$) and the daily average typing speed 39.5 in word per minute (WPM) ($n = 229$).

3.5. Self-report and direct measures of notebook computer use

There was a significant correlation between the amount of time spent using the notebook computer according to WorkPace® and the amount of time participants self-reported using the notebook computer in the College Computing and Health Survey ($N = 229$, corr = 0.25, $p < 0.05$).

There were also positive associations between the amount of time using the mouse and using the keyboard (according to WorkPace®) with answers self-reported by participants. Correlations 0.226 ($p = 0.001$, $N = 229$) and 0.204 ($p = 0.002$, $N = 225$).

3.6. Self-reported musculoskeletal discomfort and knowledge of ergonomics

Participants in experimental condition #1 (receiving external notebook accessories) and participants in experimental condition #2 (receiving external notebook accessories and participatory ergonomic training) showed a trend towards a decrease in self-reported notebook computer-related musculoskeletal discomfort at post-study as compared to pre-study. However, these results did not reach statistical significance.

All three conditions were homogeneous on their ergonomic knowledge quiz scores at pre-study. A difference in the ergonomic score was seen in each condition between pre- and post-study ($p = .001$). The post-ergonomic knowledge quiz score, on a scale of 1–10, was numerically the highest in experimental condition #2, which received participatory ergonomics training and external notebook accessories (mean = 7.349, SD = 1.254), but the difference between the groups was not statistically significant. Table 4 lists all pre- and post-study ergonomics quiz scores Fig. 2.

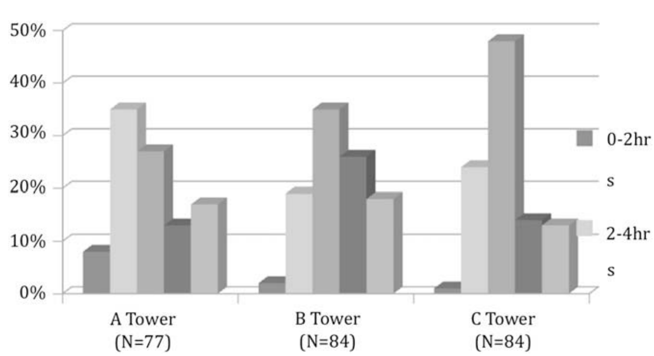

Fig. 1. . Hours spent per day using notebook computers, per experimental group, according to self-report in post-survey (A = control, B = group #1, C = group #2).

Participants who improved their post-study ergonomics quiz score, by scoring higher than their pre- study ergonomics score, had significantly less self-reported notebook computer-related musculoskeletal discomfort on their post-survey for experimental conditions #1 and #2 (students with improved post-study ergonomic scores and significantly less discomfort: Control $n = 21$, $p > 0.99$; experimental condition #1 $n = 29$, $p = 0.02$; experimental condition #2 $n = 37$, $p = 0.01$). However, the difference in improvements in ergonomics scores between experimental conditions was not statistically significant.

4. Discussion

The study design was very labor intensive, e.g., pre- and post-study photographs were taken, pre- and post-study surveys completed, many training sessions, and the exchange of monthly e-mails. However, strict reinforcement of the study requirements and reminders to participants by the researchers allowed the study to run smoothly.

Participants' self-reported notebook computer-related musculoskeletal discomfort are comparable to those reported in other studies of computer use by university students (Katz et al., 2000; Amick et al., 2003; Menendez et al., 2007) as well as those by adults working in office environments (Gerr et al., 2002).

Participants appeared to accurately self-report the amount of time using the notebook computer when compared to software that measured usage. This finding offers support for the efficacy of self-reported survey methodology. The daily amount of computer use (2.5 h daily; $n = 237$) is comparable to the daily amount of computer use by adult computer workers when measured by WorkPace® (Taylor, 2007). Taylor reported average computer use to be 12.5 h per week (2.5 h per day over a 5 day week).

Participants who used external notebook computer accessories (notebook riser, external keyboard and mouse) self-reported less notebook computer-related discomfort. Participants who used external notebook computer accessories and participated in participatory ergonomics training with follow-up, also self-reported less notebook computer-related discomfort as compared to the beginning of the study. These findings suggest that external notebook computer accessories and participatory ergonomic training may be considered effective strategies in reducing self-reported notebook computer-related musculoskeletal discomfort.

Students who improved their ergonomics quiz score had significantly less self-reported notebook computer-related musculoskeletal discomfort at post-study. The findings on both the type of intervention strategy used (external notebook computer accessories or external notebook computer accessories and participatory ergonomics training) and post-study ergonomics quiz scores support the results from the Robertson et al. (2002) study. That study reported increased knowledge of computer ergonomics by university students who participated in a participatory approach, which incorporated an instructional systems, design process and active adult learning. Although we did not have a significant difference between groups, all groups showed an increase in knowledge of ergonomics in the post-study. We might speculate that there was possible contamination between groups where participants might have informally discussed ergonomics.

Our study leaves unanswered questions such as the individual contributions of various external notebook computer accessories, e.g., keyboard, mouse, keyboard, riser on self-reported notebook computer-related musculoskeletal discomfort; the location of and time usage patterns when students self-report experiencing musculoskeletal discomfort; the impact of participatory ergonomics training without accessories; and the impact of an ergonomics computer workstation chair in the dormitory computer workstation. Future studies should address these limitations and

Table 4
Ergonomics knowledge quiz score.

Category	Significant	Borderline significant	Not significant	Difference but not significant
Self-reported notebook computer-related discomfort	Cond. #1 ($p = 0.008$) & Cond. #2 ($p = 0.007$)		Control cond. ($p = 0.23$)	
Differences in discomfort reduction	Trend across all conditions			
Association between activities done at same time as computing and discomfort			$p > 0.10$ for all conditions	
Association between discomfort and touch-typing		Cond. #1 ($p = 0.067$) Control cont. ($p = 0.083$)	Cond. #2 ($p = 0.855$)	
Association between self-reported number of breaks and discomfort			Chi-square $p = 0.80$ for all conditions	
Post-survey: Percentage of participants taking regular breaks	Increase: Cond. #2 ($p = 0.002$)			
Amount of time spent using notebook computer – WorkPace vs. self-report	Correlation – corr = 0.25			
Difference in ergonomics quiz score				Each condition – score was numerically higher
Improved post-ergonomics quiz score had less discomfort	Cond. #1 ($p = 0.02$) Cond. #2 ($p = 0.01$)		Control cond. ($p > 0.99$)	
Trend towards decrease in discomfort at post-intervention				Cond. #1, Cond. #2
Differences in typing proficiency			Across all conditions	

expand upon the previous study's findings. In particular, it is important to clarify the individual contributions of various external notebook computer accessories on self-reported notebook computer-related musculoskeletal discomfort and to understand the feasibility of using these accessories among university students.

Another limitation to the study was measuring self-reported notebook computer-related musculoskeletal discomfort at only two points: pre- and post-study. Future studies should add an Ecological Momentary Assessment (EMA) method to measure self-reported discomfort throughout the duration of the study. EMA are randomly timed assessments combined with event-contingent assessments. According to Menendez et al. (2007), "The advantage of using ecological momentary assessment techniques is randomly beeping handheld instruments increase the chance of catching responders at a time a behavior or symptom has recently been experienced, potentially reducing recall bias" (p. 289). Participants' responses to the repeated surveys should then be correlated with recorded notebook usage to ascertain patterns of computer use which might precipitate self-reported notebook computer-related musculoskeletal discomfort.

Another limitation of this study is due to attrition. Analysis was conducted on 57 students in the Control group, 85 students in condition #1, and 81 students in condition #2. Following the best effort of the research team reasons for participants' attrition included time constraints, concerns with the computer software, and lack of interest. Additional incentives may have facilitated participant retention.

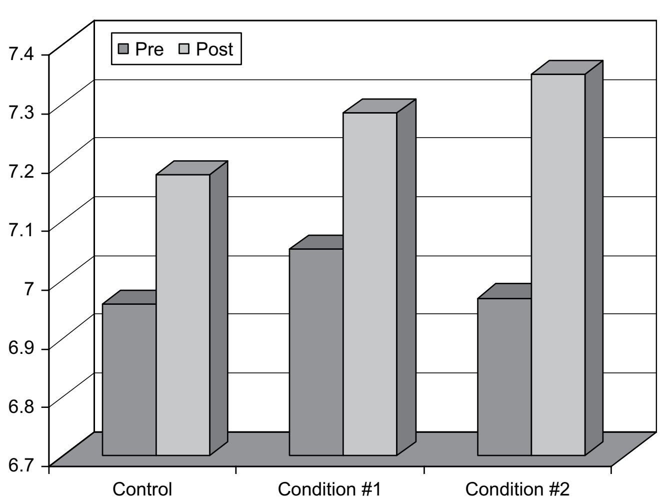

Fig. 2. . Ergonomics Knowledge Quiz Score.

5. Conclusion

External notebook accessories and participatory ergonomics training appear to contribute to a trend of decreased self-reported notebook computer-related musculoskeletal discomfort in university students. To promote the health of this country's student body and future employees, universities are encouraged to increase the availability of education on ergonomics, provide adaptable workstations in dormitory rooms, and promote proactive problem solving to prevent and decrease self-reported notebook computer-related musculoskeletal discomfort. However, more research is needed to determine the most effective ergonomics intervention for university students.

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