Comparisons of computer exposure and forearm musculoskeletal symptoms among three computer groups - The application of an external logger

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Abstract

This study utilized multi-transducer loggers for bio-signals and an integrated pointing device to develop an external logger for recording computer input activities. The purpose of this study was to compare the computer exposure and forearm musculoskeletal symptoms among three computer groups. 30 participants were recruited in this study and divided into three groups: 10 computer-document (CD) processors, 10 computer-aided design (CAD) draftsmen, and 10 online gamers. Computer use of each participant was recorded for 10 consecutive days. Questionnaire survey was conducted to collect musculoskeletal complaints in participants' upper limbs right after data collection period. Quantitative parameters computed using recorded data were daily dynamic duration and static duration, daily keystrokes, mouse clicks, wheel scrolling counts, mouse movement and dragged distance, average typing and clicking rates, and average time holding down keys and mouse buttons. Experimental results show online gamers have an average operation period of 8.2 hr/day, document processors 3.8 hr/days, and CAD draftsmen 4.8 hr/days. The online gamers have significantly higher keyboard activities than typical keyboard users, CD processors, and higher mouse activities than the typical mouse users, CAD draftsmen. However, musculoskeletal complaint in their upper limbs is not greater than that of CD processors and CAD draftsmen. This study demonstrates that online gamers exhibit similar input pattern as CD processors. There exists a complicate relationship between cumulative hazards and computer uses. Experimental results derived from onsite measurements indicate that computer use duration alone cannot accurately represent the workloads of various computer tasks. Adequate tools are needed for quantifying user computer exposure and providing detailed information for various computer tasks. Future study should further collect long-term data of computer exposure and investigate effects of personal factors such as age and gender.

Keywords：Computer exposure, Online game, Computer input, External logger

1. Introduction

Previous studies showed that prolonged computer use was positive correlation with work-related upper extremity disorders. Study investigation pointed out that the hand, wrist, and arm pain of computer operators exceeded other body parts [1,2]. Szabo (1998) study showed that 21% of work-related carpal tunnel symptoms (CTS) cases were engaged in the repeated data entry [3]. Recently, the musculoskeletal injury problems of young people caused by using computer had gradually been much account of scholars [4-8].

Jensen et al. (1998) demonstrated that musculoskeletal symptoms are more prevalent for the arm and hand operating a mouse than for the other arm or hand. Chang et al (2007) found that the daily computer average operating time exceeded three hour, it significantly increased musculoskeletal pain [10]. Chen et al identified a relationship between keyboard and mouse usage and cumulative trauma disorder (CTD) symptoms [11]. These studies suggested that percentage of time spent typing, typing speed, and force were factors likely correlated with CTDs. Factors implicated in the development of a CTD are insufficient recovery time, highly repetitive tasks, awkward posture and high force (Silverstein et al., 1996; Putz-Anderson, 1988). When these factors are combined, the risk of developing a CTD is high.

To date, many studies determined computer exposures based on computer use time, and a strong relationship exists between computer use time and risk of musculoskeletal symptoms (Chang et al., 2007; Homan and Armstrong, 2003). However, different computer tasks may have different times spent typing, mouse clicking, and mouse dragging. Determining computer exposure by total computer use time may be insufficient for discovering differences in physical workload. Therefore, the purpose of this study was to explore computer exposure and forearm musculoskeletal symptoms among three computer groups. The computer groups included computer-document (CD) processors, computer-aided design (CAD) draftsmen, and online gamers.

2. Materials and methods

2.1. Subjects

10 CD processors (aged 33.4±4.8 years), 10 CAD draftsmen (aged 31.8±5.2 years), and 10 online gamers (aged 23.5±1.5 years) were recruited in this study. Each subject self-reported using only the test PC during work and had a regular work-rest schedule and consistent work content (i.e., routine or similar computer tasks). Table 1 shows the demographic data of each group. According to an informal survey, CD processors s executed regular document processing tasks comprising data entry, document editing, accounting, and Internet browsing. The predominant computer environments of the CD processors were Microsoft Office and an information system for accounting,

purchasing, and student affairs. Draftsmen design tasks comprised computer graphing and document editing. The predominant computer environments of draftsmen were Microsoft Office, SolidWorks and CATIA (Dassault Systemes). Online gamers were young students nowadays who have the hobby in online game every day.

Table 1. Demographic data（mean ± SD）

Groups	Sex	Age (years)	Height (cm)	Weight (kg)	Seniority (year)
CD processors (n=10)	**F: n=10 M: n=2**	**33.4±4.8**	**167.2±5.0**	**64.6±5.5**	**9.5±6.4**
CAD draftsmen (n=10)	**F: n=3 M: n=9**	**31.8±5.2**	**166.6±4.8**	**65.4±7.2**	**6.8±5.8**
Online gamers (n=10)	**M: n=14**	**22.5±1.5**	**170.5±6.8**	**70.6±5.8**	**5.6±1.7**

CD computer-document; *CAD* computer-aided design.

2.2. Equipment and test procedure

Three sets of logger systems developed by Chen et al. (2009) were utilized to record subject computer activities. The system consists of a hardware logger and KMlog analytical software. The computer activities of each subject were recorded for 10 consecutive days. The research goals were explained, and detailed instructions were given to all participants before data collection. Participants provided informed consent before participating in the study. Demographic data were collected, included personal characteristics, computer use, and subjective feelings about regional pain during the past year. Pain in the neck, shoulders, arms, wrists, and upper and lower back areas were recorded. Response categories were "no pain," "mild pain," "discomforting," "distressing," and "intense" scored on a scale from 0 to 4.

Each test run was started on a weekday by an investigator who installed and initiated the hardware logger on each subject's computer at 8:00 a.m. Data recording continued for 10 consecutive days and was stopped by the investigator on day 10 at 6:30 p.m. During each test, the same keyboard, mouse set (Cordless Desktop EX111, Logitech, Taiwan) and gain settings were applied to each test PC. Each participant then performed regular work-rest activities during the test period. The unobtrusive nature of the installed logger ensured that subjects quickly forgot that they were being monitored. Therefore, participants did not likely alter their work patterns as a consequence of participating in this study.

2.3. Data processing

Parameters derived by KMlog software from recorded computer activities consist of number of workdays, total dynamic and static durations, total keystrokes, mouse click counts, wheel scrolling counts, mouse movement and distance dragged (in 1000*mickeys), average typing and clicking rates, and average time holding down keys and mouse buttons. The KMlog software computes total dynamic, static and resting durations associated with computer use based on time intervals of adjacent records. The time intervals (pause definitions) were set to 5 seconds and 30 seconds to categorize computer use time as dynamic (<5s), static or resting (>30 s) durations (Chen et al., 2009). Additionally, the dynamic durations (DD) for the keyboard and mouse usage were computed individually based on time intervals of adjacent keyboard records and mouse records, respectively (Fig. 1). Average daily exposures were computed by dividing the above PC usage parameters by the number of workdays measured during the 10-day survey period. Average typing and clicking rates (number/second) were calculated by dividing the total number of keystrokes and clicks by overall keyboard DD and mouse use DD, respectively.

2.4. Statistical analysis

Statistical analysis used SYSTAT 12.0. Group differences for all daily exposure parameters were performed by a one-way analysis of variance (ANOVA). Post hoc Bonferroni tests were conducted for multiple comparisons. Group differences and side differences (dominant vs. non-dominant) for musculoskeletal complaints in each body part were tested using the Kruskal-Wallis test and Wilcoxon signed rank test, respectively, an analytical result was considered significant at $p< 0.005$.

3. Results

Table 2 showed that computer exposure differences (operating period, speed and number of keystroke, speed and number of mouse button clicks, and mouse move No) in three groups differed significantly ($p<0.005$). Experimental results show online gamers have an average operation period of 8.2 hr/day, document processors 3.8 hr/days, and CAD draftsmen 4.8 hr/days. Post hoc results showed that online gamers have significantly higher operating period than CD processors and CAD draftsmen ($p<0.001$). The stroke speed was higher in online gamers than in CD processors and CAD draftsmen ($p<0.001$). The keystroke number was higher in online gamers than in CAD draftsmen ($p<0.001$). Because its variability is quite large, so keystroke number was not significantly higher in online gamers than in CD processors.

In mouse use, results showed click speed was higher in CAD draftsmen than in CD processors (p=0.003). The click number and move distances were higher in online gamers than in CD processors (p=0.002). But there was no difference in mouse use between online gamers and CAD draftsmen (Table 2).

In regional pains, no significant group difference existed in musculoskeletal complaints of any body part, but the shoulder and arm of dominant side had higher tendency in CAD draftsmen than in online gamers (p=0.028~0.047). However, subjects had a significantly higher number of complaints in the shoulder, arm and wrist of dominant than in those of non-dominant (p<0.002).

4. Discussion

The results show the computer average exposure (operating time) are high for three groups, and the exposure amount of daily operating period were more than 3 hours that the scholars have suggested [10]. Among three groups, the daily operating periods up to 8.2 hours for online gamers. Many studies determined that increased duration of computer use is positively associated with increased risk of musculoskeletal symptoms (Gerr et al., 2004; Chang et al., 2007). However, previous study suggests that computer exposure of different tasks not be based solely on duration of computer use (Wu et al., 2010). Cooper and Straker (1998) reported differences in shoulder muscle activity when operating a mouse and keyboard. And different biomechanical risk factors are associated with different computer tasks (Dennerlein and Johnson, 2006). Village et al. (2005) concluded that the risk of carpal tunnel syndrome increased as computer use increased, especially when using a mouse for more than 20 hours per week.

This study also showed that the online gamers have significantly higher keyboard exposure than typical keyboard users (CD processors), and higher mouse exposure than the typical mouse users (CAD draftsmen) and CD processors. The results showed overall computer exposure in online gamers were most likely higher than that of the general occupational computer operators.

Previous study suggests a relationship between musculoskeletal discomforts and the speed and force control in keystroke actions [12]. This study found that online gamers have the fastest stroke speed of keyboard, and lowest CAD draftsmen. In addition, the keyboard use of online gamers excessively concentrated on some specific keys, results in causing pressure load to concentrate in few small muscle groups. This study speculated that people addicted to online game should have a high risk of musculoskeletal injury.

Although the online gamers may have a higher risk of musculoskeletal injuries, but are not the most serious in musculoskeletal complaints of the upper extremity in this study. The results were consistent with the previous findings [17]. Even the young people frequently use computers due to computer games, but upper extremity pain were not significantly higher than in other computer users [17]. This observation shows upper extremity musculoskeletal symptoms should be complex cumulative damage. Only the quantitative records by short-term few days and questionnaire data collection may not be sufficient on behalf of actual exposure by operating keyboard and mouse for a long time. It may be because the ages of the online gamers were significantly lower about 10 years old than other both groups. Thus, some factors such a better rest - repair capacity, or because of gender difference among groups [18], may confuse the relationship between exposure and musculoskeletal injury symptoms.

For most computer users, computer exposures are not bilaterally symmetrical due to dominant hands typically carrying the bulk of both keyboarding and mouse operations. Such operation may result in shorter pauses for the dominant hand than in the non-dominant hand, furthering fatiguing dominant hands. This proposition is supported by the questionnaire results, indicating that subjects had significantly more musculoskeletal complaints in their dominant (mouse using) side than non-dominant side.

5. Conclusions

The computer average exposure (operating time) are high for three groups The online gamers have significantly higher keyboard and mouse exposures than other groups, but not greater musculoskeletal complaint of upper extremity than CAD draftsmen. Experimental results derived from onsite measurements indicate that computer use duration alone cannot accurately represent the workloads of various computer tasks. Adequate tools are needed for quantifying user computer exposure and providing detailed information for various computer tasks. Future study should further collect long-term data of computer exposure and investigate effects of personal factors such as age and gender.

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Table 2. Average daily computer exposures of document processors, draftsmen, and online gamers.

Parameters / Grous	Total operation period (hr/day)	Keyboard: Stroke speed (counts/min)	Keyboard: Keystroke (counts/day)	Mouse: Click speed (times/min)	Mouse: Click (times/day)	Mouse: Scroll (counts/day)	Mouse: Move (k mickey /day)	Mouse: Drag (k mickey /day)
CD prpocessors (n=12)	3.8 (0.9)	34.8 (13.5)	7785.5 (3598.2)	14.3 (2.9)	3224.2 (1250.3)	4085.2 (1525.4)	885.2 (304.6)	48.9 (26.3)
CAD Draftsmen (n=12)	4.8 (0.8)	7.5 (3.6)	2024.0 (816.0)	23.4 (3.7)	6594.0 (1672.6)	8531.6 (4410.5)	1743.0 (538.5)	152.0 (112.2)
Online gamers (n=14)	8.2 (2.6)	38.8 (25.2)	20250.0 (15834.5)	17.8 (8.8)	9136.4 (5940.2)	5982.5 (5292.3)	2466.0 (1580.5)	452.2 (512.4)
p_{abc}	<0.001**	<0.001**	<0.001**	0.003*	0.002*	0.043	0.002*	0.01
p_{ab}	n.s.	0.002*	n.s.	0.003*	n.s.	n.s.	n.s.	n.s.
p_{bc}	<0.001**	<0.001**	<0.001**	n.s.	n.s.	n.s.	n.s.	n.s.
p_{ac}	<0.001**	n.s.	n.s.	n.s.	0.002*	n.s.	0.002*	n.s.

Parameters / Groups	Dynaic time (hr/day)	Static time (hr/day)	Holding time (hr/day)	Keyboard rate (HZ)	Mouse rate (HZ)	Keyboard-dynamics (hr/day)	Mouse-dynamics (hr/day)	
CD prpocessors (n=12)	3.1 (0.7)	0.75 (0.26)	0.18 (0.18)	2.60 (0.50)	0.40 (0.08)	0.86 (0.44)	2.32 (0.71)	
CAD Draftsmen (n=12)	4.2 (0.7)	0.60 (0.19)	0.21 (0.11)	1.55 (0.22)	0.47 (0.08)	0.37 (0.15)	4.00 (0.74)	
Online gamers (n=14)	7.2 (2.4)	0.10 (0.34)	2.19 (4.58)	1.74 (0.51)	0.42 (0.15)	3.28 (1.80)	5.58 (2.25)	
p_{ab}	0.003*	0.003*	0.068.	<0.001**	0.230	<0.001**	<0.001**	
p_{ab}	n.s.	n.s.	n.s.	<0.000**	n.s.	n.s.	n.s.	.
p_{bc}	0.002*	0.003*	n.s.	n.s.	n.s.	<0.001**	n.s.	
p_{ac}	n.s.	n.s.	n.s.	<0.001**	n.s.	<0.001**	0.001**	

*p<0.01, **p<0.001 ; p_{abc}: difference among three groups; p_{ab} : difference between CD processors and CAD draftsmen; p_{bc} : difference between CAD draftsmen and online gamers; p_{ac} : difference between CD processors and online gamers; *CD* computer-document; *CAD* computer-aided design.

Table 3. Subjective regional pains and related response score among three groups

Groups	Neck	Dominant side: Shoulder	Dominant side: Arm	Dominant side: wrist	Non-dominant side: Shoulder	Non-dominant side: Arm	Non-dominant side: wrist	Upper back	Lower back
CD processors (n=12)	1.83 (0.83)	1.50 (0.80)	1.25 (0.62)	1.58 (0.79)	1.25 (0.62)	1.08 (0.29)	1.25 (0.62)	1.42 (0.67)	1.08 (0.29)
CAD draftsmen (n=12)	1.83 (0.94)	2.25 (0.87)	1.75 (0.87)	2.25 (0.97)	1.33 (0.49)	1.25 (0.45)	1.42 (0.51)	1.33 (0.65)	1.25 (0.62)
Online gamers (n=14)	1.79 (0.80)	1.50 (0.65)	1.07 (0.27)	2.21 (0.97)	1.14 (0.36)	1.00 (0.00)	1.07 (0.27)	1.21 (0.43)	1.43 (0.76)
p_{abc}	n.s.	0.033	0.026	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
p_{ab}	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
p_{bc}	n.s.	0.047	0.028	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
p_{ac}	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

p_{abc}: difference among three groups; p_{ab} : difference between CD processors and CAD draftsmen; p_{bc} : difference between CAD draftsmen and online gamers; p_{ac} : difference between CD processors and online gamers; *CD* computer-document; *CAD* computer-aided design.

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