MUSCULOSKELETAL SYMPTOMS AND LAPTOP COMPUTER USE AMONG COLLEGE STUDENTS

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Laptop computers are widely used by college students for academic and leisure activities (Cortes, Hollis, Amick, & Katz, 2002). However, there is limited research that identifies risk factors for musculoskeletal discomfort during laptop computer use in this population. This dissertation includes two studies: Study 1: This survey study explored characteristics of laptop computer use and relationships between laptop-related risk factors and discomfort; Study 2: This randomized cross-over study examined the effects of three most common laptop workstation setups on upper body postures, discomfort, and task productivity.

Thirty students were recruited from the University of Pittsburgh. The survey was a self-administered questionnaire. Subjects' posture were videotaped while typing for 10 minutes in six laptop workstation setups (desktop sitting, chair sitting, lying prone, lying supine, floor sitting, and lap sitting), and the three most common workstation setups were analyzed. Body angles were digitized at 10-time points and averaged using ImageJ. Typing style was identified using the Keyboard-Personal Computer Style Instrument. Discomfort was determined using a 10-cm VAS. Task productivity was assessed by typing speed and accuracy. Data were analyzed by ANOVAs and Bonferroni post-hoc comparisons.

Subjects were primarily female (83.3%), with a mean age of 26.0±7.3, and white (63.3%). Survey results showed that the most common workstation setups were desktop sitting, followed by lying supine and chair sitting. There were no statistically significant relationships between laptop-related factors (duration and type of workstation setup) and discomfort. Most body angles were significantly different between the three workstation setups: neutral wrists and ulnar deviation, upright trunk, and greater shoulder flexion during desktop sitting; greater neck flexion, wrist extension, and ulnar deviation during chair sitting; less neck flexion and greater wrist flexion and trunk extension during lying supine. For typing style, subjects showed large differences in static postures among the workstation setups. Less discomfort and faster typing speed were observed during desktop sitting, followed by lying supine, and then chair sitting.

Overall more neutral postures and less discomfort were observed during desktop sitting, followed by lying supine and chair sitting. These findings highlight the importance of laptop workstation setup choice for preventing potential musculoskeletal problems.

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PREFACE

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1.0 INTRODUCTION

Laptop computers are widely used by college students for writing assignments, presenting research projects, and leisure activities (e.g., playing games, watching movies, or communicating with friends). According to two large annual surveys at the University of Texas (Wolff, 2006) and the University of South Carolina (Crews, Brown, Bray, & Pringle, 2007), more than 50% of students have laptop computers, and growth rate for students' laptop computer ownership has dramatically increased with an average of 65% from 2002 to 2004 and 227% from 2001 to 2006. Another large web-based survey (Salaway, Caruso, Nelson, & Dede, 2007) of 15,000 college students has reported that more students own a laptop computer (75.8%) rather than a desktop computer (58.1%). In addition, replacement time of a laptop computer is shorter than that of a desktop computer: approximately 34.5% of laptop computers are replaced in less than one year, while only 8.1% of desktop computers are replaced in less than one year.

With the increasing use of laptop computers by college students, more students are reporting musculoskeletal symptoms (MSS) while using their laptop computers. This may be, because the design of laptop computers (e.g., small monitor and keyboard and lack of a separate keyboard and monitor position adjustment) can promote awkward body postures (Hamilton, Jacobs, & Orsmond, 2005; Jacobs et al., 2009; Raps & Nanthavanij, 2008). However there are only three survey studies that have examined laptop computer use and MSS in college students. This scarcity of information about characteristics of laptop computer use makes it difficult to summarize and generalize the potential risk factors associated with MSS in laptop computer operators.

In addition to these design problems, laptop computer operators are at high risk for developing MSS due to environmental variability in their use. Laptop computers are widely used in many environments (e.g., classroom, bedroom, or airport) and workstation setups (e.g., desktop, chair, lap sitting, lying supine, or lying prone). Harris and Straker (2000) suggested that laptop computer operators may experience MSS due to the variety of non-traditional laptop workstation setups that may place their body into awkward postures. However, there have been a limited number of published research studies that have investigated the effects on postures of laptop computer use in several laptop workstation setups. Understanding postural risk factors related to different laptop workstation setups may provide insight into how laptop computer operators can use their laptop computers safely.

The overall purpose of this dissertation is to extend knowledge about potential laptop-risk factors that may be associated with MSS in college students. The general aims of this study are to:

- Develop a valid and reliable survey instrument (Laptop Computer User Screening Survey [LCUSS])
- Describe characteristics of laptop computer use in college students
- Examine the relationship between laptop-related risk factors and physical discomfort
- Examine the effects of the three simulated laptop workstation setups on upper body postures, physical discomfort, and task productivity

In Chapter 2, we provide a literature review and background information on potential risk factors associated with musculoskeletal disorder (MSD)/MSS in laptop computer operators. This literature review provides the rationale for the aims addressed in this dissertation by identifying what risk factors have been documented in previous research studies.

In Chapter 3, we report the results of a survey study that describes the characteristics of laptop computer use (e.g., location of laptop computer use, laptop transportation methods, laptop-related tasks, laptop specifications, duration of laptop computer use, laptop workstation setup, and attitude toward laptop computers) in our sample population. The LCUSS was developed from a literature review of empirical studies and then it was checked for validity and reliability through a content validation process by a panel of content reviewers and test-retest reliability. We also examined the relationships between laptop-related risk factors (i.e., duration of laptop computer use and type of laptop workstation setups) and MSS (i.e., physical discomfort).

In Chapter 4, we report the results of a randomized repeated cross-over study which examined the effects of the three most common laptop workstation setups (i.e., desktop sitting, chair sitting, and lying supine) on upper body postures, physical discomfort, and task productivity. Although six simulated laptop workstation setups (i.e., desktop sitting, chair sitting, lap sitting, floor sitting, lying supine, and lying prone) were recorded during data collection, we only analyzed the three most common laptop workstation setups based on the findings of the survey study in Chapter 3.

In Chapter 5, the findings of the two studies are summarized. The implications of these findings regarding the laptop-related risk factors for MSS are also discussed.

2.0 POTENTIAL RISK FACTORS ASSOCIATED MUSCULOSKELETAL DISORDERS AND SYMPTOMS IN LAPTOP COMPUTER OPERATORS: LITERATURE REVIEW

This chapter provides background information for this dissertation. Since there have been a limited number of published reports on the use of laptop computers and risk factors for their use, this chapter reviews the potential risk factors associated with musculoskeletal disorders (MSD) and symptoms (MSS) in desktop computer operators. The specific sections considered in this chapter include the following areas: (1) musculoskeletal disorders and symptoms; (2) MSD/MSS and computer use; (3) potential risk factors for MSD/MSS; (4) college students and MSS associated with computer use; and (5) risk factor exposure assessments for MSD/MSS.

2.1 MUSCULOSKELETAL DISORDERS AND SYMPTOMS

According to the Bureau of Labor Statistics (2009), the term of musculoskeletal disorders (MSD) refers to conditions that involve the nerves, tendons, muscles, and supporting structures of the body. MSD have also been called several different names, such as ‘cumulative trauma disorder,’ ‘repetitive strain or stress injury,’ ‘occupational overuse syndrome,’ and ‘activity-related pain syndrome,’ because repeated exposure of the same muscle or tendon has been hypothesized to be a risk factor for injury and inflammation to the affected area. However these classifications are rarely accepted in scientific research field, because of their diagnostic uncertainty. Therefore, the terminology of MSD has been selected as the common language in epidemiological research field, because it represents diagnostic condition without assumptions about possible causative factors (Boocock et al., 2009). The most common types of MSD are carpal tunnel syndrome, De Quervains' disease, epicondylitis, tendonitis, thoracic outlet syndrome, tension neck syndrome, and lower back pain (Kuorinka, Forcier, & Hagberg, 1995). Musculoskeletal symptoms (MSS), on the other hand, are characterized by discomfort, pain, numbness, tingling, aching, stiffness, and burning with various signs, such as swelling, redness, and difficulty moving a particular body part (Armstrong, Foulke, Joseph, & Goldstein, 1982; Kuorinka et al., 1995; Silverstein, Fine, & Armstrong, 1987). Early detection of MSS helps prevent the onset of potential MSD, because physicians often diagnose MSD based on these symptoms.

MSD/MSS have been identified as the most common reason for reported work-related illness, productivity loss, and long-term sick leave (Brady et al., 1997; Hartman, Oude Vrielink, Huirne, & Metz, 2003; Putz-Anderson, 1988). In 2009, the Bureau of Labor Statistics reported that there were 317,440 MSD cases requiring a median 10 days away from work, 2 days longer than the median for all other types of work related to injuries. Aside from personal pain, health care cost for the nation’s work force associated with MSD imposes a heavy burden on both the community and the individual. In the United States (U.S.), conservative health care costs associated with MSD were estimated at over $1.25 trillion in 1994 (Brady et al., 1997). Data from Washington State also indicated that one third of workers’ compensation costs in private industry in the U.S. were estimated to be caused by MSD and exceeded $20 billion between 1990 to 1998 (Silverstein, Viikari-Juntura, & Kalat, 2002). In the United Kingdom, an estimated

4.2 million working days were lost in 1995 due to upper extremity MSD, and costs associated MSD were estimated to be at least £200 million (Graves, Way, Riley, Lawton, & Morris, 2004).

2.2 MSD/MSS AND COMPUTER USE

The associations between MSD/MSS and computer use have been a public health concern since the mid 1980s, when the use of computers increased dramatically in the working environments (Hopkins, 1990). In 2003, the U.S. Census Bureau reported 70 million American households (62%) had one or more personal computers, up from 56% in 2001 (U. S. Census Bureau, 2005). In the U.S., it was estimated that approximately 224 million people (76% of all U.S. adults) used computers in 2004 (United Nations, 2007). The use of portable computers (i.e., laptop computers) is also growing rapidly. In 2008, laptop computer shipments in the U.S. market exceeded desktop computer shipments for the first time in the history of the industry (International Data Corporation, 2008). In Japan, laptop computer sales have already reached 40% of total computer output (Villanueva, Jonai, & Saito, 1998). In China, laptop computer sales have reached 34.5% (2.19 million units) of the total Chinese personal computer market in 2008 and accounted for nearly 40% in 2009 (Shenshen, 2009). It is not surprising that laptop computers have become popular, because they have the advantage of being portable, lightweight, and space and energy saving, enabling the users to work anywhere and anytime (Moffet, Hagberg, Hansson-Risberg, & Karlqvist, 2002; Saito, Miyao, Kondo, Sakakibara, & Toyoshima, 1997).

Table 2-1. Prevalence of MSD/MSS in Computer Use

Study	Study Design	*N*	Prevalence			
			Neck/Shoulder		Hand/Arm	
			MSD	MSS	MSD	MSS
Kamwendo et al. (1991)	Cross-sectional	420	–	62.0%[1] 34.5%[2]	–	25.0%[1] 15.0%[1]
Hales et al. (1994)	Cross-sectional	518	9.0%[1 and 3] 6.0%[1 and 4]	–	12.0%[1 and 6] 7.0%[1 and 5]	–
Bergqvist et al. (1995b)	Cross-sectional	260	> 20.0%[1]	61.5%[1]	9.0%[1]	30.0%[1]
Palmer et al. (2001)	Cross-sectional	1871	–	38.6%[2]	–	18.4%[2]
Gerr et al. (2002)	Prospective cohort	632	6.0%[2]	10.0%[2]	2.0%[2]	4.0%[2]
Brandt et al. (2004)	Prospective cohort	6943	1.4%[1 and 3] 0.6%[1 an4]	10.6%[1 and 3] 7.6%[1 and 4]	–	–
Cagnie et al. (2007)	Cross-sectional	512	–	45.5%[1]	–	–

Note. MSD = musculoskeletal disorders; MSS = musculoskeletal symptoms; [1]1-year prevalence; [2]7-day prevalence; [3]Neck; [4]Shoulder; [5]Elbow; [6]Hand and wrist

With such rapid increases in the use of computers, the health concerns about MSD/MSS among computer operators have been increasing. The U.S. Department of Labor (2000) stated these concerns as follows: "Internet computer use accounts for a significant number of MSD each year, and occupational computer use is growing." Epidemiological studies have demonstrated a high prevalence of MSD/MSS among computer operators: the prevalence of MSS ranges from 7.6 – 63.0% for neck/shoulder (N/S) and 4.0 – 30% for hand/arm (H/A); and the prevalence of MSD ranges from 0.6 – 62.0% for N/S and 2.0 – 25.0% for H/A (see Table 2-1) (Bergqvist et al., 1995b; Brandt et al., 2004; Cagnie et al., 2007; Gerr et al., 2002; Hales et al., 1994; Kamwendo et al., 1991; Palmer et al., 2001). It is apparent that there is little agreement concerning the prevalence of MSD/MSS among computer operators; these differences may be due to differences in the measurement time-point used in the period prevalence calculation. Given the high prevalence of MSD/MSS among computer operators, the identification of contributing risk factors may have important public health implications.

2.3 POTENTIAL RISK FACTORS FOR MSD/MSS

This section describes potential risk factors for MSD/MSS in laptop computer operators. The specific issues considered in this section include four subsections: (1) awkward posture; (2) forceful exertion; (3) duration and rest breaks; and (4) individual factors. All of these risk factors are used to provide item rationale for the initial question set of the survey instrument developed for this dissertation studies.

2.3.1 Awkward posture

The most commonly cited risk factor in computer operators has been awkward postures. Several epidemiological studies have suggested that awkward body posture is the strongest risk factor associated with musculoskeletal problems (Bjelle, Hagberg, & Michaelson, 1981; Chaffin, 1973; Liss, Jesin, Kusiak, & White, 1995; Punnett, Fine, Keyserling, Herrin, & Chaffin, 2000; Sakakibara et al., 1987; van den Heuvel, van der Beek, Blatter, & Bongers, 2006).

In general, computer-related awkward posture is static or fixed postures of body parts. Sustained postural muscle activity may cause localized muscle fatigue, which may develop even during low-force exertion. In a cohort study by Garg et al. (2002), subjects reported high perceived ratings of localized discomfort and muscle fatigue in their shoulders after 15 minutes of holding a weight at 5% maximum voluntary contraction (MVC). Similarly, Sjogaard et al. (1986) also observed the occurrence of perceived muscle fatigue during isometric knee extension at 5% MVC, though blood flow was adequate to the muscle. Several studies support that static or fixed postures are associated with musculoskeletal problems (Ekberg et al., 1994; Milerad & Ekenvall, 1990). In a prospective cohort study with 1334 industrial workers, Ariens et al. (2001) found a significant relationship between neck symptoms and prolonged neck flexion of over 20° for more than 70% of working time and sedentary sitting posture for more than 95% of working time.

Desktop computer work with awkward upper body postures demonstrates the most consistent relationship to MSD/MSS (see Table 2-2). Several studies have reported that desktop computer operators work in awkward postures that place them at potential risk for developing MSD/MSS (Jensen et al., 1998; Karlqvist, Hagberg, Koster, Wenemark, & Nell, 1996; Marcus et al., 2002). These awkward postures include increased neck flexion greater than 20° (Ariens et al., 2001), shoulder flexion greater than 35° (Marcus et al., 2002), ulnar deviation greater than 20° (Hunting, Laubli, & Grandjean, 1981; Liu et al., 2003), radial deviation greater than 5° (Marcus et al., 2002), and wrist extension greater than 15° (Moore & Garg, 1994). In cross-sectional studies with desktop computer operators, Hunting, Laubli, and Grandjean (1981) and Sauter, Schleifer, and Knutson (1991) demonstrated that ulnar deviation greater than 20° was a significant predictor of hand disorders and discomfort, specifically carpal tunnel syndrome. Carpal tunnel pressure on the median nerve has been shown to be influenced by extreme body postures during desktop computer work: wrist extension (Keir, Bach, & Rempel, 1998a; Liu et al., 2003; Rempel, Keir, & Bach, 2008; Werner, Armstrong, Bir, & Aylard, 1997); wrist flexion (Armstrong, Castelli, Gaynor Evans, & Diaz-perez, 1984; Rempel et al., 2008); and forearm deviation greater than 45° of pronation (Keir, Bach, Hudes, & Rempel, 2007; Rempel, Bach, Gordon, & So, 1998). In a prospective epidemiological study with 632 desktop computer operators, Marcus et al. (2002) reported that static typing with an inner elbow angle of more than 121° and a radial wrist deviation of more than 5° while using a mouse, were also associated with MSD/MSS among computer operators.

Prolonged and awkward postures of neck and shoulder are the most common awkward postures associated with MSD/MSS in the upper body (Bergqvist et al., 1995b; Hales et al., 1994; Kamwendo et al., 1991; Palmer et al., 2001). Several studies suggest that MSD/MSS of the neck and shoulder were associated with sustained neck flexion, head inclination of 56° or more, head rotation greater than 20°, and increased shoulder flexion and abduction in desktop computer operators (Chaffin, 1973; Hunting et al., 1981; Marcus et al., 2002; Sauter et al., 1991). In general, computer operators spend long hours at their computers without adequate breaks. And while most people consider their hands, wrists, arms, and fingers as being used most, the neck and shoulder generally maintain static postures (Kamwendo, Linton, & Moritz, 1991). The prevalence of MSD/MSS for the neck/shoulder is higher than for the hand/arm among desktop computer operators (see Table 2-1). These differences may result from the different movements of muscles and pathophysiological reactions between hand/arm and neck/shoulder regions, because the neck/shoulder muscles are more static than hand/arm muscles during computer work. According to Visser and van Dieen (2006), it is unlikely that a single comprehensive pathophysiological mechanism exists that explains tissue damage in the neck and shoulder. This damage may be caused by Ca^{2+} accumulation in the active motor units, insufficient blood supply, and metabolite removal in muscle compartments with large numbers of active motor units.

Table 2-2. Awkward Postures Associated with MSD/MSS Among Desktop Computer Operators

Study	Study design	*N*	Neck/Shoulder		Hand/Arm	
			MSD	MSS	MSD	MSS
Ferguson & Duncan (1974)	Case-control	29	–	•Shoulder abduction ↑	–	•Wrist ulnar deviation ↑ •Wrist extension ↑
Hunting et al. (1981)	Cross-sectional	162	•Head inclination of > 56° •Head rotation of > 20°	•Higher keyboard height from table (i.e., elbow flexion of < 75°)	•Wrist ulnar deviation of > 20°	•Insufficient space to rest hand arm
Sauter et al. (1991)	Cross-sectional	333	–	•Shoulder flexion ↑	–	•Placing keyboard above elbow height (i.e., decreased elbow flexion) •Wrist ulnar deviation ↑
Bergqvist et al. (1995a)	Cross-sectional	353	•Placing keyboard below elbow height (i.e., lower than 2.5 cm; elbow extension)	–	–	–
Marcus et al. (2002)	Prospective cohort	632	•Inner elbow angle of < 121° •Downward head tilt ↑ (i.e., neck flexion) •Placing keyboard above elbow height (i.e., decreased elbow flexion)	•Inner elbow angle of < 121° •Downward head tilt ↑ (i.e., neck flexion) •Placing keyboard above elbow height (i.e., decreased elbow flexion)	•Wrist radial deviation of > 5° while using mouse •Wrist extension ↑ during keyboarding	•Wrist radial deviation of > 5° while using mouse •Wrist extension ↑ during keyboarding
Liu et al. (2003)	Prospective cohort	45	–	–	•Wrist extension of > 20° has been associated with carpal tunnel syndrome ↑	–

Table 2–2 (continued).

Study	Study design	*N*	Neck/Shoulder		Hand/Arm	
			MSD	MSS	MSD	MSS
Juul-Kristensen et al. (2004)	Prospective cohort	5033	–	–	–	•Monitor below eye height (i.e., increased neck flexion)
Cagnie et al. (2007)	Cross-sectional	720	–	•Prolonged neck flexion •Various short periods of movements with the neck •Often working in static postures for a prolonged time •Often making repetitive movements per minutes •Often sitting for a prolonged time	–	–
Rempel et al. (2008)	Cross-over	20	–	–	•Wrist extension of > 30° has been associated with carpal tunnel pressure ↑ •Radial wrist deviation of > 15° has been associated with carpal tunnel pressure↑	–

Note. MSD = musculoskeletal disorders; MSS = musculoskeletal symptoms

Laptop computers are different than desktop computers, in terms of the interaction between inherent design characteristics and biomechanical aspects of the human body. These differences may place laptop computer operators more at risk for MSD/MSS than desktop computer operators, because the use of a laptop computer promotes more awkward postures. The first aspect of laptop computers associated with awkward postures is the design and construction of laptop computers that violate basic ergonomic requirements; namely that users can change the positions of keyboard and monitor independently for an appropriate viewing and typing angle. Most current laptop computers have their monitors fixed to the main body of the keyboard with a hinge, so users cannot adjust the position (e.g., angle, height, and distance) between keyboard and monitor (Harris & Straker, 2000; Saito et al., 1997; Saito et al., 2000). This lack of flexibility in the arrangement of components may restrict the users from assuming a comfortable position while operating their laptop computers. Adjustment of height and slope between the keyboard and the monitor is one frequently recommended change in a computer workstation setup, because a comfortable reach zone for the keyboard and the monitor varies among people with different height, weight, and length of upper limbs. The Cornell University ergonomics website (2004) explained this phenomenon as follows: “The reason is simple with a fixed design. If the keyboard is in an optimal position for the user, the monitor isn't, and if the monitor is optimal the keyboard isn't. Consequently, laptop computers are excluded from current ergonomic design requirements because none of the designs satisfy this basic need.”

Several studies have found that as the monitor height was lowered, laptop computer operators showed greater head and neck flexion (Burgess-Limerick, Plooy, & Ankrum, 1998; Villanueva, Sotoyama, Jonai, Takeuchi, & Saito, 1996), increased muscle activity (Bauer & Wittig, 1998; Villanueva et al., 1997)(Bauer & Wittig, 1998; M. B. Villanueva et al., 1997), and increased physical discomfort (Sauter et al., 1991). Straker et al. (1997) found that laptop computer operators showed significantly greater neck flexion and head tilt to view a lower laptop monitor and to use the small keyboard, compared to the desktop computer operators. This result was supported by Villanueva et al. (1998) and Saito et al. (1997), who reported that laptop computer operators flexed their neck more than desktop computer operators. Furthermore, electromyography (EMG) results of neck muscles in laptop computer operators were significantly higher than those in the desktop computer operators (Saito et al., 1997; Villanueva, Jonai, & Saito, 1998). These results suggest that since laptop computer devices cannot be adjusted, subjects' awkward body postures may increase biomechanical overload on the muscle tissues. Table 2-3 provides a summary of research studies that compare the postural risk factors between laptop and desktop computer operators.

Given these concerns of postural limitations caused by the laptop computer's inherent features, Sommerich, Starr, Smith, and Shivers (2002) examined the postural effects using a stand-alone laptop computer vs. a laptop computer with external input devices; one group used an external mouse, while the other group used an external keyboard. The results showed that use of a stand-alone laptop induced significantly more postural fixity and non-neutral postures in neck, shoulder, and elbow, compared to the other two groups with external input devices (i.e., external mouse and keyboard). The inherent restrictions of laptop computer design (e.g., a small monitor and keyboard and the lack of a separate keyboard and monitor position adjustment) may promote awkward or constrained body postures that may be associated with MSD/MSS. Therefore, to prevent potential musculoskeletal problems, it is important to determine the postural risk factors present in laptop computer working environment.

Another postural problem relevant to laptop computers is the effect of various laptop workstation setups on their use. Since laptop computers have easy portability as the primary advantage, they can be used in many different workstation setups. With laptop computers, people are free to lie on the floor or bed, lean back on a couch in the hotel lobby, or even stand up. In a survey study with school children aged 10 to 17, laptop computer operators reported that they used their laptop computers in a wide variety of locations, such as school (98%), home (94%), transport (10%), or other areas of school (2%) (Harris & Straker, 2000). These results were supported by Sommerich, Ward, Sikdar, Payne, and Herman (2007), who reported that laptop computer operators worked in various locations and workstation setups. Laptop workstation setups assumed by laptop computer operators included desktop sitting (84%), followed by lying prone (60%), floor sitting (58%), stool sitting (30%), and sitting with laptop computer on the lap (50%). Harris and Straker (2000) suggested that physical discomfort experienced by laptop computer operators may be from the variety of non-traditional laptop workstation setups that may put their body into awkward postures. For example, lying prone may induce a laptop computer operator to increase their neck extension and muscle load of neck and shoulder to sustain the position.

In a laboratory study by Moffet, Hagberg, Hansson-Risber, and Karlqvist (2002) with eight healthy subjects, the effect of two laptop workstation setups (i.e., desktop sitting and lap sitting) was evaluated on upper body postures and muscle activities. The results found that subjects assumed less neck flexion, backward trunk inclination, and wrist extension when laptop computers were placed on desks than in their laps. However, higher muscle activity levels in the trapezius and deltoid muscles were found in desktop sitting. Although the results did not suggest the ideal laptop workstation setup, these findings suggest that the choice of laptop workstation setup is important, and postural exposures can be influenced by workstation setup. More recently, Asundi et al. (2010) compared upper body postures on three laptop workstation setups (i.e., desktop sitting, lap sitting, and laptop sitting with a lap desk) using a motion analysis system. They found that laptop computer operators in lap sitting showed greater head down tilt, viewing angle, wrist extension, and physical discomfort than those in desktop sitting. There were no differences between the lap and lap desk sitting.

In conclusion, the use of laptop computers may result in greater risk for MSD/MSS than the use of desktop computers, due to their inherent designs and various laptop workstation setups. The main problems are likely to be neck and upper limb discomfort, all due to restricted viewing angles, inability to adjust the height and position of the keyboard and monitor, and small size of the keyboard and monitor. All these problems may be exacerbated, because laptop computers allow users great variety in workstation setups, when laptop computers are used away from controlled environments with appropriate equipments and postures. Therefore, it is important to evaluate physical risk factors in various laptop workstation setups and to recommend appropriate workstation setups to laptop computer operators.

Table 2-3. Comparison of Postural Risk Factors Between Desktop and Laptop Computer Operators

Study	Study design	*N*	Independent variable(s)	Dependent variable(s)	Results
Straker et al. (1997)	Cross-over	16	•Desktop •Laptop (Desk sitting)	•UE Posture: angle •Discomfort: VAS •Performance: speed and number of errors	•Significantly increased neck flexion and head-down tilt in laptop computer operators compared to desktop computer operators •Greater discomfort in laptop computer operators, but not significant •No difference in performance
Saito et al. (1997)	Cross-over	10	•Desktop •Laptop (Desk sitting)	•UE posture: angle and viewing distance •Muscle activity: EMG	•Significantly increased head-down tilt and short viewing distance in laptop computer operators compared to desktop computer operators •No difference in neck angle •Significantly increased EMG level of the neck muscles in laptop computer operators compared to desktop computer operators
Villanueva et al. (1998)	Cross-over	10	•Desktop •Laptop with various monitor sizes (Desk sitting)	•UE posture: angle •Muscle activity: EMG •Discomfort: VAS •Performance: speed and number of errors	•Significantly increased neck flexion, trunk forward bending, and inward rotation of shoulder in laptop computer operators compared to desktop computer operators •Above values were more increased, as the size of laptop computers decreased •Significantly increased neck, trapezius, deltoid, and extensor ulnaris muscles in laptop computer operators compared to desktop computer operators •Significantly increased neck muscle, as the size of laptop computers decreased •The highest discomfort was reported on a laptop computer of 6.1 inches •No difference in performance
Szeto & Lee (2002)	Repeated measures	21	•Desktop •Laptop •Sub-laptop (Desk sitting)	•Neck posture: angle •Performance: speed, accuracy, and efficacy	•Significantly increased neck flexion •Significantly better performance on desktop computers compared to laptop computers

Note. UE = upper extremities; VAS = visual analogue scale; EMG = electromyography

2.3.2 Forceful exertion

Force is the amount of muscular efforts required to perform work. Exerting high forces can increase the fatigue and physiological damage to the muscles, tendons, and joints (Armstrong, 1986). Several research studies have indicated the hand force of over 30 Newton (N) as a potential risk factor for the development of MSD/MSS (Chiang et al., 1993; Silverstein et al., 1987), yet other studies have not found that force may be a risk factor for these disorders and symptoms (Moore & Garg, 1994).

Although keyboarding requires relatively low-force exertions, force applied to the keyboard may be a risk factor for MSD/MSS due to the highly repetitive nature of typing (Wahlstrom, 2005). It has been estimated that some professional typists can exert more than 46 N of force while typing, typically 3 – 5 times the necessary force (Marras & Karwowski, 2006). The Board of Standards Review of the Human Factors and Ergonomics Society (BSR-HFES 100, 2002) has recommended that the minimum force required to electrically activate the key should be between 0.25 N and 1.5 N. Rempel et al. (1997) also suggested that in order to minimize the biomechanical loads to forearm tendons, keyboard users should exert forces of less than 0.47 N.

Epidemiological studies have linked forceful fingertip loading tasks to carpal tunnel syndrome (Keir, Bach, & Rempel, 1998b; Rempel, Keir, Smutz, & Hargens, 1997), MSS (Feuerstein, Armstrong, Hickey, & Lincoln, 1997), and MSD (Armstrong, Foulke, Martin, Gerson, & Rempel, 1994). Typing speed may influence keyboard strike force that may be associated with risk factor for potential MSD. Although a laboratory study by Sommerich, Marras, and Parnianpour (1996) did not show a significant relationship between key strike force and typing speed, this might have been due to the greater number of keystrokes among the faster typists. When the five subjects who participated in the study typed at three speeds (i.e., slower than preferred, preferred, and faster than preferred), there were significant positive correlations between the typing speed and keyboard reaction force.

However, these previous studies have been focused on the relationship between desktop computer keyboarding and applied fingertip force. Laptop computer keyboards usually use a scissor-switch membrane key type that is generally quiet and requires little force to press, while desktop computers use a mechanical key that is more durable and provides louder auditory feedback (i.e., sound of key click) than other keyboard types. The effects of auditory feedback were examined by Gerard, Armstrong, Rempel, and Woolley (2002), who found that higher auditory feedback caused a reduction of 10 – 20% in typing force. Bufton, Marklin, Nagurka, and Simoneau (2006) also suggest that lower auditory feedback of laptop computer keyboard may induce excessive overstrike force, even though laptop computers have lower key stiffness than the desktop computer keyboard.

Carrying a laptop computer is an additional forceful exertion for laptop computer operators which is not a consideration for desktop computer operators. Most desktop computers are fixed in one place due to their size and weight, while laptop computers are often carried by users. Although laptop computers have been getting lighter and smaller, many people carry them with other supplementary accessories, such as power supply cords, spare batteries, or external peripherals; adding weight to their laptop bag. The handling of a laptop bag with heavy loads, particularly if it continues for long periods of time, is a potential risk factor for MSD/MSS (Karwowski, 2001). Some surveys with schoolchildren have found that over 60% of students who used laptop computers reported discomfort when carrying their laptop computers, and shoulder discomfort was reported by more than 38% of students (Harris & Straker, 2000; Manchester & Cayea, 1998; McDonald, 1995).

Few studies have reported on the prevalence of MSS related to carrying a laptop computer, but the effect of carrying load in backpacks is well documented. In general, the effect of load carrying has been measured by physiological and biological changes at different backpack loads. Significant changes in oxygen consumption (Hong & Brueggemann, 2000), gait pattern (Hong & Brueggemann, 2000), and trunk and head postures (Goodgold et al., 2002; Grimmer, Dansie, Milanese, Pirunsan, & Trott, 2002) have been found in schoolchildren carrying backpacks of 10% bodyweight or more. Pasco et al. (1997) examined the postural effects between one-strap bag over shoulder and two-strap backpack, with constant bag weight of 17% body weight. The results demonstrated that one-strap bags promoted greater lateral trunk bending, asymmetric shoulder elevation, and angular motion of head and trunk, compared to the two-strap backpacks.

In conclusion, keyboard operation requires forceful fingertip exertions to press the keys. It has been shown that keyboard reaction force may be affected by typing speed and auditory feedback of keyboard. In addition to these risk factors, carrying a laptop computer results in an additional burden that may be associated with potential MSD/MSS in the upper body. If people carry other supplementary accessories (e.g., power supply cords or batteries) or textbooks in their laptop bag, they may be at more risk for developing MSD/MSS.

2.3.3 Duration and rest breaks

The amount of time spent engaged in continuous computer work has been cited as a risk factor for MSD/MSS of the neck, shoulder, and upper limbs. (Blatter & Bongers, 2002; Fredriksson et al., 2002; Gerr et al., 2002; Jensen, Finsen, Sogaard, & Christensen, 2002; Karlqvist, Tornqvist, Hagberg, Hagman, & Toomingas, 2002; Karlqvist et al., 1996; Tittiranonda, Burastero, & Rempel, 1999). A systematic review of 9 longitudinal studies reported that the duration of computer use was consistently associated with MSD/MSS (IJmker et al., 2007). These findings may be explained using the theory of muscle overuse. Physical discomfort may be due to an overuse of low threshold muscle fibers causing damage at muscle cell level, also known as the Cinderella hypothesis (Hagg, 2000). In general, computer work is characterized by prolonged and repetitive task with low external force demands. According to the Cinderella hypothesis, prolonged low-level static contraction during working recruits type I muscle fibers, and this may lead to chronic impairment of energy metabolism in selected muscle units.

In several research studies, a strong dose-response relationship has been established between duration of computer use and prevalence of musculoskeletal problems; as daily computer usage time increased, the odds of reporting daily musculoskeletal problems consistently increased (odds ratios mostly ranged 0.99 to 2.86) (Bernard, Sauter, Fine, Petersen, & Hales, 1994; Jensen, 2003; Lassen et al., 2004). In a cross-sectional study (Schlossberg et al., 2004) with 206 graduate students, computer duration was identified as a risk factor for upper extremity MSS. Hours of computer use were grouped into four levels (i.e., < 20, 20 – 29, 30 – 39, and 40 hr/week), and the results were compared to control group. Each increased hour of computer use was associated with an increased odds ratio of reporting symptoms. This finding was supported by Nakazawa et al. (2002) and Jensen (2003) suggesting that the duration of computer use, particularly for more than 4 hours per day, was significantly associated with MSS. Conversely, in a prospective study by Juul-Kristensen et al. (2004), the prolonged computer work-time (i.e., 25% of time, 50% of time, 75% of time, and almost all time) was not a significant risk factor related to the discomfort of upper extremity.

To prevent the onset of musculoskeletal problems, rest breaks away from intensive computer operation are important for individuals who use computers for long periods of time. Several researchers have proposed that the risk of MSD/MSS is increased in computer operators who have limited rest break opportunities (Bergqvist et al., 1995b; Tittiranonda et al., 1999). Rest breaks allow computer operators to obtain relief from all of the physical stains imposed by continuous and constrained computer work, such as static muscle fatigue, reduced blood circulation, and inflammation in tendons, muscles, and nerves (Carter & Banister, 1994). Although the recommended interval between breaks and computer works is different among researchers, frequent and short breaks have been proposed as a highly beneficial rest to restore the ability to continue working (Fisher, Andres, Airth, & Smith, 1993; Henning, Jacques, Kissel, Sullivan, & Alteras-Webb, 1997). In other words, taking a break of 5 minutes every half hour is better than 10 minutes once an hour, although the total duration is the same (Floru, Cail, & Elias, 1985; Henning et al., 1997). Research has found that discomfort in upper extremities and eye was significantly reduced by supplementary rest break interventions for computer operators (Galinsky, Swanson, Sauter, Hurrell, & Schleifer, 2000; Ong, 1990). And still other research has found that short rest breaks showed improvements in performance (e.g., typing speed or error rate) (Floru et al., 1985; Gao et al., 1990). It is assumed that the performance improvement may be mediated by increased alertness and decreased muscle fatigue produced by extra rest breaks (Ong, 1990).

In conclusion, prolonged computer use, particularly more than 4 hours per day, is significantly associated with the development of MSD/MSS. In order to prevent these potential risks, frequent short breaks have been recommended as a means of reducing static loads in computer operators. Therefore, it is important to identify accurate information about duration of laptop computer use and rest breaks.

2.3.4 Individual factors

Individual factors have been defined as non-work, personal, or demographic factors that can contribute to or help prevent MSD/MSS. These factors include gender, age, obesity, or cigarette smoking (National Research Council and Institute of Medicine, 2001). In addition, we consider that recreational activity is a potential risk factor of MSD/MSS, because participation in non-occupational activities (e.g., sports or music-related instrument activities) may cause highly repetitive or forceful movements.

2.3.4.1 Gender

In most of the studies which have examined the risk factors between upper extremity MSD/MSS and computer use, women have had higher prevalence rates compared to men (Bernard et al., 1994; Brandt et al., 2004; Gerr et al., 2002; Katz et al., 2000). Gerr et al. (2002) reported that women had significantly greater risk factors for upper extremity MSD/MSS than men. In epidemiological studies with college students, Katz et al. (2000) and Chang et al. (2007) reported that female students had a significantly higher prevalence of symptoms compared to the male students. Juul-Kristensen et al. (2004) also examined gender differences as a risk factor of computer work in a prospective study. For all the regions of the upper body, a higher percentage of women (22%) than men (11%) had physical discomfort in the shoulder.

In almost all studies regarding gender differences, women had an almost two-fold risk compared to men. There are a variety of hypotheses to explain the differences based on psychological and biological mechanism. One possible explanation for this increased risk for women is that women may pay more attention to symptoms, and respond more aggressively than men (Muller, 1990). Some studies have demonstrated that women tend to have more indirect reactions to a pain event that include emotion-focused coping, seeking social support, and relaxation, whereas men rely on direct action, such as problem-focused coping and talking problems down (Unruh, 1996).

Another possible explanation is that underlying biological differences may predispose women to have more discomfort. A review by Tittiranonda et al. (1999) suggests that some gender differences in discomfort might be caused by differences in metabolism, physical structures, and hormonal variations which could influence the biological mechanisms of pain transmission, pain sensitivity, and pain perception. Although there are a number of plausible explanations for gender differences in the prevalence of musculoskeletal problems, most research studies suggests that women have more vulnerable biological and psychological natures (Unruh, 1996).

2.3.4.2 Age

Aging is associated with loss of skeletal muscle mass and, consequently, a decline in muscular strength, endurance, and recovery from injury (National Research Council and Institute of Medicine, 2001). These biological changes also include a reduction in the number of active motor units (Doherty, Vandervoort, Taylor, & Brown, 1993; Kirkendall & Garrett, 1998) and in muscle morphology and metabolism (Kirkendall & Garrett, 1998). In general, the decrease in muscle strength begins around age 40, and is most rapid after age of 60 (Faulkner, Brooks, & Zerba, 1990; Kirkendall & Garrett, 1998). Therefore, older individuals are more vulnerable to injury and fatigue compared to younger individuals. Several studies have reported a high rate of musculoskeletal discomfort in older individuals, in particular for physically demanding occupations (de Zwart, Broersen, Frings-Dresen, & van Dijk, 1997; de Zwart, Frings-Dresen, & van Duivenbooden, 1999).

For computer operators, higher age is significantly associated with MSD/MSS (Bergqvist et al., 1995b). Several research studies suggest that older computer operators are more fragile to localized muscle fatigue that may be associated with MSD/MSS, possibly due to age-related alterations in all the major body systems (e.g., cardiovascular, metabolic, respiratory, and neuromuscular) (Jensen, Ryholt, Burr, Villadsen, & Christensen, 2002; Kirkendall & Garrett, 1998).

Another age-related problem is computer vision syndrome for the elderly (Madhan, 2009). Focusing ability and tear production normally decrease with age (Sen & Richardson, 2007). Although rarely studied, vision problems may be related to MSD/MSS, because people who wear bifocal or trifocal glasses tend to involuntarily lean their heads back or forward to see through their glasses (Aaras, Horgen, Bjorset, Ro, & Thoresen, 1998; Wiholm, Richter, Mathiassen, & Toomingas, 2007).

2.3.4.3 Obesity

In general, obesity is a very strong risk factor for carpal tunnel syndrome. The relationship between body mass index (BMI) and carpal tunnel syndrome is explained by the accumulation of fat tissues or synovial thickening in the carpal tunnel, which causes pressure to the median nerve (Werner, Armstrong, Bir, & Aylard, 1997). In addition, many obese people use their upper extremities as weight bearing limbs to change their center of gravity to support body fat (i.e., when rising from a chair, they usually have to use their arms to push up). This may put additional pressure on the median nerve and account for the increased discomfort (Hooper, 2006).

Other than carpal tunnel syndrome, excessive weight poses an increased risk for musculoskeletal problems, particularly for the rotator cuff tendinitis. In a case-control study with 311 patients who were required rotator cuff surgery, the risks for the shoulder surgery were significantly higher for individuals with BMI of 35 or above (Wendelboe et al., 2004). In obese people, accumulation of fat may lead to atherosclerosis and decreased blood flow to the rotator cuff muscle (Hooper, 2006).

2.3.4.4 Cigarette smoking

Several studies have been found the associations between smoking and MSD/MSS for the neck (Makela et al., 1991), shoulder (Ekberg et al., 1994), and leg (Brage & Bjerkedal, 1996), while other studies have not found an association (Pietri et al., 1992). Although several plausible explanations for these associations have been proposed by researchers, there is no obvious mechanism for the associations between smoking and musculoskeletal problems. One plausible explanation is that smoking may cause nutritional deficiencies in the musculoskeletal system and joint structures through vasoconstriction, hypoxia, defective fibrinolysis, or atherogenic effect (Frymoyer et al., 1983). Metabolic or direct toxic effects seem possible as well. These biological effects may make muscle tissues sensitive to sudden high load stress causing acute injury and to prolonged or repetitive low-load stress causing chronic trauma. Furthermore, recovery of muscle tissue may also be delayed or incomplete (Kelsey, Githens, & O'Conner, 1984).

2.3.4.5 Recreational activities

Some non-occupational or recreational activities, such as sport, dance, or playing a musical instrument, have been linked with MSD/MSS (Gosheger, Liem, Ludwig, Greshake, & Winkelmann, 2003; Marras & Granata, 1995). Although most individuals engage in the right amount of recreational and leisure activities as outside interests, sometimes these activities include highly repetitive or forceful movements of the upper and lower extremities (Adams, 1965; Green & Rayan, 1997; Miller, Lowry, Meardon, & Gillette, 2007).

In addition, musculoskeletal problems relevant to performing arts or music have been frequently cited as associated with MSS (Bruno, Lorusso, & L'Abbate, 2008; Hagberg, Thiringer, & Brandstrom, 2005). Specifically, musicians working with an elevated arm position (e.g., violinists, violists, flutists, and trumpet players) had a higher prevalence of the neck and shoulder pain than those working in a more neutral position (Nyman, Wiktorin, Mulder, & Johansson, 2007).

2.4 COLLEGE STUDENTS AND MUSCULOSKELETAL SYMPTOMS ASSOCIATED WITH COMPUTER USE

This section discusses the rationale for selecting college students as the population group in this dissertation and how musculoskeletal problems are associated with laptop computer use in college students.

College students, both undergraduates and graduates, spend many hours each day at computers, because computers are essential for carrying out routine academic activities, as well as social and personal activities (Cortes et al., 2002; Saito et al., 1997). Several cross-sectional studies with college students have reported a high prevalence (41 – 81%) of desktop computer-related upper extremity MSS (Chang et al., 2007; Hamilton et al., 2005; Hupert et al., 2004; Jenkins et al., 2007; Katz et al., 2000; Menendez et al., 2007; Schlossberg et al., 2004). Furthermore, duration of daily desktop computer use longer than roughly 4 hours was significantly associated with MSS among students (Chang et al., 2007; Schlossberg et al., 2004).

However, these studies only examined the prevalence of symptoms for desktop computer operators, not laptop computer operators. With the increasing availability of wireless network and laptop initiatives that provide or lease new laptop computers to freshman students on the college campus, a laptop computer is essential for today's college students for essay writing, web surfing, or communicating with others (Weaver & Nilson, 2005). According to a survey at the University of Texas at Austin from 2002 to 2004, the ownership of laptop computers increased from 22% to 45% for undergraduates, while desktop computer ownership decreased from 75% to 55% (Wolff, 2006). The trend toward increased laptop computer ownership have also been shown in a survey conducted by EDUCASE from 2005 to 2007 with 15,000 undergraduates (Salaway et al., 2007). The survey revealed that 75.8% of students have laptop computers, while 58.1% of students have desktop computers.

Given the increased use of laptop computers by college students, there is a potential for increase in exposure to risk factors associated with MSS. Although there are several research studies that reported associations between laptop computer use and MSD/MSS in the general population (Harris & Straker, 2000; Jonai, Villanueva, Takata, Sotoyama, & Saito, 2002; Sommerich et al., 2007; Straker et al., 1997; Villanueva et al., 1998), only three studies examined musculoskeletal discomfort in college laptop computer operators (Hamilton et al., 2005; Jacobs et al., 2009; Raps & Nanthavanij, 2008). In a survey study of 111 female college students by Hamilton et al. (2005), the associations between laptop computer use and musculoskeletal symptoms were examined. Although there were no significant relationships between physical discomfort and laptop computer use, 90% of students who used a laptop computer reported musculoskeletal discomfort, compared to 80% for those who used a desktop computer. Hamilton et al. (2005) suggest that further research is needed to investigate the associations between laptop computer use and musculoskeletal discomfort. Jacobs et al. (2009) examined how college students used their laptop computers, and what ergonomic strategies (i.e., provide the external notebook accessories and participatory ergonomic training) might be effective in reducing musculoskeletal symptoms. This study reported that 66% of students experienced musculoskeletal symptoms while using a laptop computer before starting ergonomic training. There was a significant reduction in self-reported symptom from pre- and post- survey in students who received external notebook accessories (78% to 65%) and in those who received accessories and participatory ergonomic training (61% to 49%), but no changes in those in the control group (58% to 55%). More recently, Raps and Nanthavanij (2008) also found that over 50% of students experienced discomfort related to laptop computer use, and the major body parts reported by students for discomfort were their necks (60.8%), shoulders (53.9%), and backs (55.9%).

In conclusion, many college students use their laptop computers for their academic and leisure activities, and the potential awkward postural habits when using a laptop computer may develop future musculoskeletal problems (Cortes et al., 2002; Hamilton et al., 2005). As demonstrated in the risk factors section, laptop workstation setups are different from that of desktop computers, in terms of a laptop’s inherent design and the diversity of workstation setups; these differences may place laptop computer operators more at risk for musculoskeletal discomfort than desktop computer operators. Therefore, it is important to understand the associations between laptop computer use and musculoskeletal discomfort for college students. College students are a population well suited for studying the effects of laptop computer use on musculoskeletal discomfort, because of their role as knowledge workers in a computing-dominated career.

2.5 EXPOSURE ASSESSMENT METHODS

This section provides an overview of various methods for assessing exposure to risk factors for MSD/MSS. This information is used as the basis to consider respective advantages of assessment methods and to support the rationale for selecting the assessment method used in the current study. There are three general categories of commonly used physical exposure assessments to estimate potential risk factors related to MSD/MSS: (1) self-reports; (2) observational methods; and (3) direct measurement methods.

2.5.1 Self-reports

In musculoskeletal epidemiological studies, self-report methods can be used to collect data on the prevalence of postures, the frequency of movements, or the presence of other physical agents in the past and present via interview, questionnaire, or diaries. Self-report methods are appealing due to their relative ease of administration and low expense compared to other methods. In addition, these methods allow researcher to recruit a large population sample within a short period of time (David, 2005; Marras & Karwowski, 2006). However, as subjective self-reports are prone to be more easily influenced by other factors, the resulting information may be potentially less reliable and valid. Spielholz, Silverstein, Morgan, Checkoway, and Kaufman (2001) reported that self-reports were the least precise assessments, consistently over estimating exposures for each of the measured factors (i.e., angle and force) compared to the observational and direct measurement. Therefore, researchers often use self-report in conjunction with other measurements, such as observational or direct methods (Burdorf & Laan, 1991; Wiktorin, Karlqvist, & Winkel, 1993).

2.5.2 Observational methods

Observational measurement methods are either field-based or video-based. In a field based measurement, a trained observer assesses workplace exposures using a checklist or summary format. These can document predetermined activities or catalogue actions (Ketola, 2004). Although these methods have been widely used for their simplicity (Kilbom, 1994; Stetson, Keyserling, Silverstein, & Leonard, 1991), they do not provide sufficiently detailed information on changes in exposure during task performance (Marras & Karwowski, 2006).

Video-based methods allow the analyst more detailed and reproducible evaluations as they can code and review the data on videotapes either by hand or computer. In the computer, it is also possible to analyze time codes on various time based events (e.g., tasks, postures, and hand exertions) (Keyserling, Armstrong, & Punnett, 1991). For example, in a study by Armstrong et al. (1982), the researcher sampled postures several times a second and classified wrist postures using five categories: neutral, flexion, extreme flexion, and extension. Video-based analysis is generally the most appropriate observational method to measure the risk factors and to define the work activities for large scale epidemiological studies, because it allows the analysts sufficient time to estimate the posture of various body parts. Although video-based methods still have potential systematic biases, such as behavioral effects from the presence of camera and occluded views of performance (Spielholz et al., 2001), it has the advantages of being inexpensive, feasible, and accurate.

2.5.3 Direct measurement methods

Direct measurement (e.g., electromyography, goniometer, electromyography, and biomechanical measurement) is the most accurate and precise method to obtain postural exposure information. A variety of methods have been developed that rely on sensors attached directly to the skin to measure exposure variables. These methods have added benefit of measuring force and joint posture, but they have weaknesses, such as high cost, invasiveness, calibration, instrument malfunction, and long training. Thus, although direct method may be most accurate, combined method from questionnaire, interviews, and observational methods may be provide the best method of measuring postural data (Marras & Karwowski, 2006).

In conclusion, although direct measurements have been considered the most accurate and reliable measurement, modern video observation methods have the advantage of providing less time consuming data collection while maintaining satisfactory accuracy. Spielholz et al. (2001) comparing self-report, video observation, and direct measurement demonstrated that video observation generally matched the results from direct measurement more closely than the self-report questionnaire. However, after adjusting psychophysical scales as a confounding factor, self-report results showed increased agreement with those of direct measurement.

2.6 SIGNIFICANCE

In the current study, the link between musculoskeletal symptoms (MSS) and laptop computer work in college students is examined. MSS include discomfort, pain, numbness, stiffness, and tingling, aching, and burning sensations. These symptoms have been used to diagnose musculoskeletal disorders (MSD). Therefore, identifying the risk factors for MSS is important as it may prevent the development of MSD. Although there are several studies that have examined the associations between laptop computer use and MSS (Harris & Straker, 2000; Jonai et al., 2002; Sommerich et al., 2007; Straker et al., 1997; Villanueva et al., 1998), there are only three studies that assess if the use of laptop computers is associated with MSS among college students (Hamilton et al., 2005; Jacobs et al., 2009; Raps & Nanthavanij, 2008). In addition, although laptop computer operators work in many laptop workstation setups (e.g., desktop sitting, chair sitting, lying supine, lap sitting, etc.), only two laboratory research studies have compared the effects of different laptop workstation setups on body postures and MSS (Asundi et al., 2010; Moffet et al., 2002). Therefore, this study contributes to scarce research on laptop computer use that may be associated with MSS (i.e., physical discomfort). Specifically, the current study is important for three reasons.

First, this study focuses on college students who frequently use laptop computers. As an increasing number of college students enter computer-intensive occupations following graduation, computer-related MSS may have a significant effect on their productivity and professional future career plans. As described above, there are only three survey studies that explore the characteristics of laptop computer use and the association between laptop computer use and MSS in college students. The absence of this information creates a gap in understanding the potential risk factors related to laptop computer use among college students. This study may partially fill this gap and provide information to prevent potential MSS/MSD in college students.

Second, this study examines the effect of the three most common laptop workstation setups (i.e., desktop sitting, chair sitting, and lying supine) on upper body postures, musculoskeletal discomfort, and task productivity. In general, laptop computers are widely used in various locations and workstation setups. However there are only two laboratory studies that have examined laptop computer use in different laptop workstation setups. This limited information about the effects of laptop workstation setups makes it difficult to summarize postural risk factors and generalize the findings in laptop workstation setup. Understanding postural risk factors related to laptop computer environments may provide insight into how laptop computer operators can use their laptop computers more safely.

And third, this study increases knowledge of laptop computer use, in terms of characteristics of laptop computer use and postural risk factors that may be associated with MSS. This information could have major implications for occupational therapists (OTs) interested in evaluation or wellness programs in laptop-related workplaces for the prevention of potential MSD. OTs who are knowledgeable regarding physical, psychiatric, and interpersonal aspects of human and environment, can help workers prevent injuries and allow them to return after an injury. This study provides information about the characteristics of laptop computer use and potential risk factors associated with laptop workstation setup. These findings may be useful for OTs who want to identify the postural risks in laptop workstation setup and to provide recommendations.

3.0 POTENTIAL RISK FACTORS AND CHARACTERISTICS OF LAPTOP COMPUTER USE ASSOCIATED WITH MUSCULOSKELETAL SYMPTOMS IN COLLEGE STUDENTS: SURVEY STUDY

3.1 BACKGROUND AND SIGNIFICANCE

Many college students use laptop computers to do academic-related activities in class and around campus, such as research assignments, presentations, or data analyses, as well as leisure activities (e.g., game, movie, or internet chat). According to two large annual surveys conducted with college students by the University of Texas at Austin from 2002 to 2004 (Wolff, 2006) and by the University of South Carolina from 2001 to 2006 (Crews et al., 2007), laptop computer ownership had dramatically increased by more than 50%, while desktop computer ownership had decreased to less than 50%. More recently, a survey study (Salaway et al., 2007) found that college students' laptop computer ownership had increased from 52.8% in 2005 to 75.8% in 2007, and younger students were more likely to use laptop computers rather than desktop computers. Despite the increasing popularity of laptop computer use in college students, there have been few studies that identify how college students use their laptop computers, or what factors related to laptop computer use affect the students' health.

Prolonged computer use has been considered a risk factor for musculoskeletal symptoms (MSS). These symptoms include discomfort, pain, numbness, tingling, aching, stiffness, and burning (Kuorinka et al., 1995). Epidemiological studies have reported a high prevalence (41% – 96%) of upper extremity MSS related to desktop computer use in college students (Chang et al., 2007; Hamilton et al., 2005; Hupert et al., 2004; Katz et al., 2000; Menendez et al., 2009). In a cross-sectional study by Hupert et al. (2004), 41% of college students who had computer-related MSS reported functional limitations in their academic activities, and 23% of college students reported taking medication for their symptoms. However, these research studies focused on general or desktop computer use, not on the laptop computer use. Only three survey studies have examined the relationships between laptop computer use and MSS in college students (Hamilton et al., 2005; Jacobs et al., 2009; Raps & Nanthavanij, 2008). With the rapid increase of laptop computer ownership in college students, it is important to characterize laptop-use patterns and to examine the relationships between laptop computer use and MSS.

The literature review in Chapter 2 describes several risk factors associated with potential musculoskeletal disorders (MSD)/MSS in laptop computer operators. These risk factors include awkward body posture, forceful exertion (e.g., force related to keystroke and carrying a laptop computer), duration of computer use and rest break, and individual factors (e.g., gender, age, obesity, cigarette smoking, and recreational activities). Although we report several risk factors for MSD/MSS that may be associated with laptop computer use, some factors are derived from research studies that targeted desktop computer operators, not laptop computer operators. The scarcity of research studies that examine the effects of laptop computer use patterns associated with MSD/MSS makes it difficult to summarize risk factors and generalize the findings in laptop computer operators.

Self-report surveys are useful for assessing potential risk factors and collecting behavioral patterns at a relatively low cost and with easy administration, compared to direct or observational methods (David, 2005). However, subjective self-reports are prone to underestimate or overestimate respondent' behaviors due to undesirable exposures, such as recall, social desirability, or mood. Furthermore, weaknesses in self-report may arise from respondent literacy, comprehension, or question interpretation (Spielholz et al., 2001). In order to minimize these weaknesses in survey, it is important to develop a specific and well designed survey by assessing the validity and reliability of the instrument.

This chapter describes how we developed the survey instrument, Laptop Computer User Screening Survey (LCUSS). We then used the LCUSS to describe characteristics of laptop computer use in college students and to examine the relationships between laptop-related risk factors (i.e., duration of laptop computer use and percentage of time spent using each type of laptop workstation setup) and MSS.

3.2 RESEARCH DESIGN AND METHODS

3.2.1 Research aims

This descriptive survey study describes the characteristics of laptop computer use in college students and evaluates the relationships between laptop-related risk factors and physical discomfort. In addition, we report how we developed the LCUSS, including a content validation process by a panel of experts and test-retest reliability. This study addressed the following research aims and questions:

- Research aim 1: Develop a valid and reliable survey instrument, the LCUSS
- Research aim 2: Describe the characteristics of laptop computer use (e.g., location of laptop computer use, laptop transportation methods, laptop-related tasks, laptop specifications, duration of laptop computer use, laptop workstation setups, and attitude toward the laptop computers) in college students
- Research aim 3: Examine the relationship between laptop-related factors (i.e., duration of laptop computer use and percentage of time spent using each type of laptop workstation setup) and physical discomfort in the upper extremity
    - Research question 3.1: Is there a relationship between duration of laptop computer use and average laptop-related discomfort?
    - Research question 3.2: Is there a relationship between percentage of time spent using each type of laptop workstation setup and average laptop-related discomfort?

3.2.2 Research design

This cross-sectional descriptive study used a survey methodology, and the procedures for the study are presented in a flowchart in Figure 3-1. The development of the survey instrument, Laptop Computer User Screening Survey (LCUSS), is described in section 3.2.4.

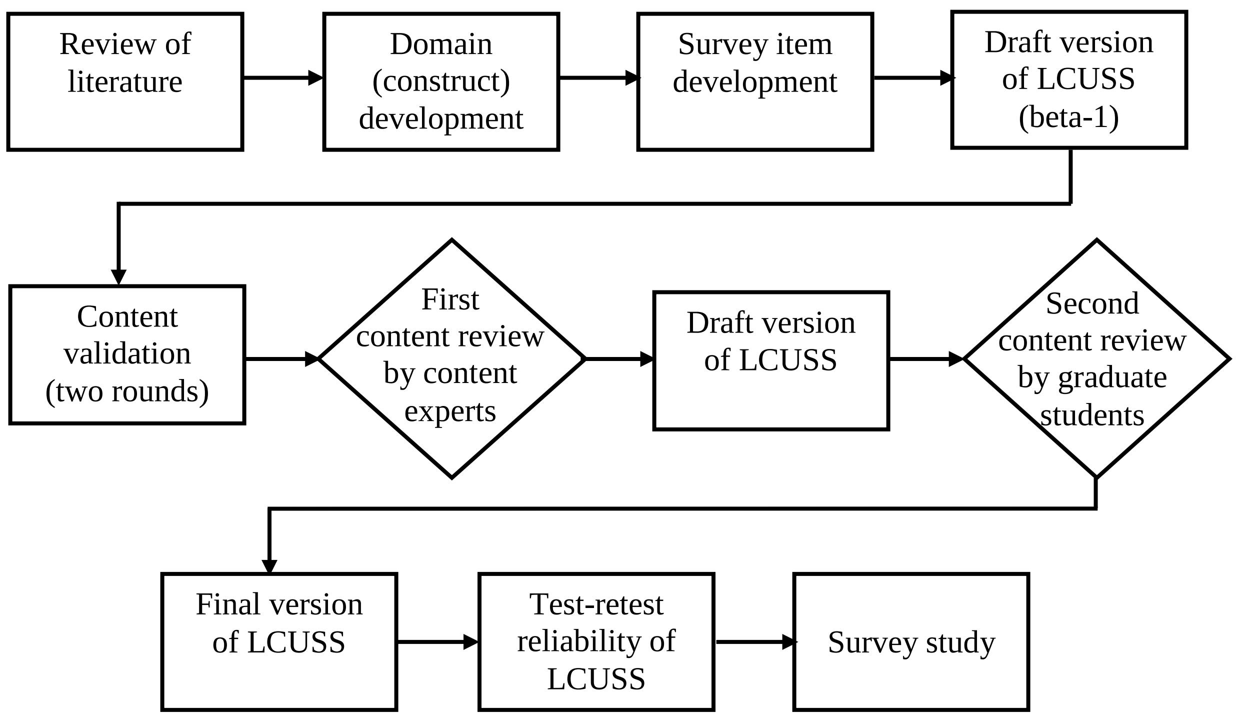


Figure 3-1. Flowchart of survey study

3.2.3 Participants

The subject population for the survey was college students, who were recruited from the University of Pittsburgh. Inclusion criteria were: (1) undergraduate or graduate students; (2) current use of a laptop computer; (3) no co-morbidities of the upper extremity, such as neurological disorders or fractures; (4) the ability to tolerate the survey task for 30 minutes. Exclusion criteria were: (1) presence of current musculoskeletal injuries in the back, neck, shoulder, and upper limbs.

Subjects were recruited using advertising flyers that included research purpose, procedure, benefit, and inclusion/exclusion criteria (see Appendix F). In addition to the recruitment using the flyers, Master of Occupational Therapy (MOT) students were invited to participate in the research study through means of a research invitation letter (see Appendix G). Written consent was obtained prior to participation in the study.

3.2.4 Instrumentation

The instrument used in this study was a paper-and-pencil self-administered questionnaire. The survey instrument was developed for this study through a literature review, content validation process, and reliability test. The section 3.2.4 describes the instrument development (Research Aim 1).

3.2.4.1 Constructing the survey items

Preliminary survey items were developed from the empirical studies that reported characteristics of computer use in both desktop and laptop computer operators, and explored risk factors that were related to MSD/MSS. Before constructing the survey items, the researcher determined the topic domains based on the literature review. The following 12 domains are addressed in the LCUSS with a total of 75 items: (1) demographic information; (2) location of laptop computer use; (3) laptop transportation methods; (4) laptop-related tasks; (5) laptop specifications; (6) usage time; (7) laptop workstation setup; (8) overall laptop related discomfort; (9) student health related role functioning; (10) attitude toward the laptop computer; (11) recreational activities; and (12) previous and current health status. Description and response scales for each survey item are provided in the following section. Although we describe the laptop-related risk factors for MSD/MSS in the literature review (Chapter 2), the rationale for each section is also provided.

In developing the items, scales, and design layout of the LCUSS, the researcher followed principles of survey research suggested by Aldridge and Levine (2001). For example, the researcher used simple and clear words, and complete sentences when constructing survey items. If there were ambiguous terms, a brief explanation or picture were provided next to questions. Open-ended questions were not used in the LCUSS, because respondents might find it difficult to answer the questions or need a longer time for completion of the survey (Aldridge & Levine, 2001; DeVellis, 2003; Dillman, 2007; Presser, 2004; Thomas, 2004; Weisberg, 2005).

<u>Section 1 – Demographic information</u>

Demographic information section (14 items) included date of birth, gender, height, weight, ethnicity, race, dominant hand, marital status, enrollment status, college entrance and graduation years, class level, residence classification, and current college residence. Among these 14 items, 9 items were multiple choice scales, and 5 items had response textboxes to enter specific numbers, such as birth date, height, and weight.

Rationale: Gathering basic demographic information allows the researcher to examine trends and differences in the study sample. In addition, these data were used to identify if the subjects participating in the survey were representative of a college student population (Green, Camilli, & Elmore, 2006).

Section 2 – Location of laptop computer use

Location of laptop computer use section (2 items) contained information about where students used their laptop computers, and the reasons for the selection of these locations. Locations were defined as library, campus classroom, campus computer lap, home, cafe, and transportation (e.g., in bus, car, or airplane). Survey respondents were asked to assign a percentage for each answer choice based on a total of 100 percent. Respondents were also asked to assign the rank 1 (most important) to 6 (least important) to determine their reason for the selection of location (i.e., accessibility of wireless internet, presence of electrical outlet, presence of chair and desk, presence of comfortable chair, and location is convenient).

Rationale: Laptop computers are used in a wide variety of locations and, thus, may be set up in less than ideal workstation setup with inappropriate furniture or equipments (e.g., desks, chairs, external devices). These unsuitable laptop workstation setups may foster adoption of awkward body postures (Harris & Straker, 2000; Sommerich et al., 2007). This information may enhance our understanding of how or why college students chose certain location.

Section 3 – Laptop transportation methods

Laptop transportation methods section (3 items) collected information about carrying methods of laptop computers and supplementary external devices, and the severity of physical discomfort experienced while transporting laptop computers. Methods of transporting laptop computers were as follows: bag or briefcase with handle; over the shoulder bag or briefcase; rolling bag or briefcase; and in a backpack. Supplementary external devices were classified as external mouse, battery, keyboard, and disk drive, AC adaptor, and extension cord. Respondents were required to check all possible answers out of the choices from a list.

Physical discomfort associated with each transportation method was assessed using the Visual Analogue Scale (VAS) (see Figure 3-2). The VAS is 10-cm horizontal line; 0 indicates 'no discomfort' to the left of the line, while 10 indicates 'unbearable discomfort' to the right of the line. Respondents placed an 'X' mark between the two extreme values to represent their discomfort severity for each laptop transportation method. The reliability and validity of VAS have been well established for measuring discomfort or pain intensity (Bijur, Silver, & Gallagher, 2001; Downie et al., 1978; Gallagher, Bijur, Latimer, & Silver, 2002; McCormack, Horne, & Sheather, 1988). In the VAS adopted in the LCUSS, the researcher included 'Not applicable; N/A' response choice to increase the response rate and quality of collected data (Iarossi, 2005).

(1) Bag or briefcase with handle	**N/A** ☐	**No Discomfort**	**Unbearable Discomfort**
(2) Over the shoulder bag or briefcase	**N/A** ☐	**No Discomfort**	**Unbearable Discomfort**
(3) Rolling bag or briefcase	**N/A** ☐	**No Discomfort**	**Unbearable Discomfort**
(4) In your backpack	**N/A** ☐	**No Discomfort**	**Unbearable Discomfort**
(5) Other (If other method specified in #3.1)	**N/A** ☐	**No Discomfort**	**Unbearable Discomfort**

Figure 3-2. Visual analogue scale adopted in item 3.3 'discomfort related to laptop transportation methods'

Rationale: Carrying a laptop computer is a major risk factor for MSD/MSS of the neck and shoulder. Some research studies found that over 44% of students reported physical discomfort associated with carrying their laptop computers (Harris & Straker, 2000; Sommerich et al., 2007). Shoulder discomfort was the most frequently cited body part related to carrying laptop computers (Harris & Straker, 2000; Sommerich et al., 2007). Carrying laptop computers in the shoulder bag was significantly associated with discomfort of the shoulder (Sommerich, 2002), while using a backpack or rolling bag were less risky for MSD/MSS (UC Berkeley, 2007; University of Sunderland, 2001). Therefore, we included these items in the LCUSS, because carrying loads may affect potential MSD/MSS of upper body parts.

<u>Section 4 – Laptop related tasks</u>

Laptop related tasks section (1 item) included information about the types of tasks that students engaged in most often when using their laptop computers. The types of tasks were as follows: word processing; presentations; analysis or spreadsheets; CourseWeb or online courses; library search; web surfing to collect work related resources (e.g., assignment or research); scheduling; look up contacts; communication with others (e.g., internet chat or chat room); shopping; check news, weather, or sports; check e-mail; watch movies or videos; pay bills; and play games. Respondents were asked to choose their top three task activities, and then ranked these activities from 1 (most frequent) to 3 (least frequent).

Rationale: Describing the type of tasks students perform using their laptop computers allows the researcher to understand how important the laptop computers are for students' college life. Recently, Sommerich et al. (2007) reported that laptop computers were used for a greater variety of tasks than other writing means (i.e., paper or desktop computer). Most students used their laptop computers not only for internet searches, but also for academic (e.g., research, homework, or calculation) and leisure activities (e.g., communication, shopping, or video game) (Raps & Nanthavanij, 2008; Sommerich et al., 2007; Wolff, 2006). Identifying type of laptop-related tasks may also help to ascertain the potential for more risky postures, because different task activities require different movements and postures. Hamilton (1996) reported that significantly more subjects showed greater head flexion and variability in typing task than those in reading and mouse tasks. Dennerlein and Johnson (2006) also demonstrated that typing tasks were associated with greater ulnar deviation and postural variability of arm and hand, whereas mouse tasks were associated with less neutral shoulder and more constrained posture. These research studies suggest that the type of tasks may affect awkward body postures.

<u>Section 5 – Laptop specifications</u>

Laptop specifications section (5 items) consisted of: (1) laptop computer model; (2) type of input devices (e.g., mouse, trackball, joystick, touch pad, track point, keyboard, and numeric keypad); (3) type of external peripherals (e.g., webcam, speakers, and microphones); (4) laptop computer weight (e.g., less than 2.5 lbs, 2.6 – 4.9 lbs, 5 – 6.9 lbs, and 7 lbs or more); and (5) monitor size. All items used multiple-choice response scales. A picture was used to clarify the monitor size item.

Rationale: There are numerous designs of laptop computers and input devices. Variability of designs may have different effects on MSD/MSS, because each model of laptop computers has a different weight and size that may require different body postures. Several studies have examined the design effects of laptop computers and input devices (Hengel, Houwink, Odell, van Dieen, & Dennerlein, 2008; Swanson, Galinsky, Cole, Pan, & Sauter, 1997). Smaller laptop monitor size increased more constrained and flexed upper body postures (Sommerich, Joines, & Psihogios, 2001; Villanueva et al., 1998; Villanueva et al., 1996), and presence of external input devices (e.g., external keyboard, mouse, or numeric keypad) increased the use of neutral postures and discomfort relief (Berkhout, Hendriksson-Larsen, & Bongers, 2004; Sommerich et al., 2002).

<u>Section 6 – Usage time</u>

Usage time section (5 items) identified duration of laptop and desktop computer use and breaks while using the laptop computers: (1) the percentage of time that students spent working on the laptop and desktop computers per week; (2) the duration of time in years that students used any laptop computers from first-time use; (3) the overall amount of time in hours that students spent on their laptop computers per day; (4) the average amount of time in hours that students spent continuously on their laptop computers per day without breaks; and (5) the typical amount of time in minutes that students spent on break. First item (i.e., computing time of laptop and desktop computers) asked respondents to assign a percentage of time spent with laptop and desktop computer uses based on a total of 100 percent. Other three items (i.e., length of years having a laptop computer, duration of daily laptop computer use, and duration of continuous laptop computer use) used response textboxes to enter specific numbers of usage time. Regarding the last item (i.e., frequency of the typical rest breaks), respondents were asked to check one of total 8 response choices (i.e., 1 = none, 2 = < 5 min, 3 = 5 – 10 min, 4 = 11 – 15 min, 5 = 16 – 20 min, 6 = 21 – 25 min, 7 = 26 – 30 min, and 8 = > 30 min).

Rationale: The duration of computer use (Blatter & Bongers, 2002; Fredriksson et al., 2002; Jensen, Finsen, Sogaard, & Christensen, 2002; Tittiranonda et al., 1999) and frequency of rest breaks (Bergqvist, Wolgast, Nilsson, & Voss, 1995b; Tittiranonda et al., 1999) are considered potential risk factors for MSD/MSS. Several studies have shown a strong relationship between MSD/MSS of the upper extremities and computer use of more than 5hr/day (Nakazawa et al., 2002), 6 hr/day (Blatter & Bongers, 2002), and 15 hr/week (Gerr et al., 2002). Computer operators usually concentrate their attention on a monitor to identify visual information that is manually typed by keyboard or mouse. This work style may not allow computer operators to realize the initial sign of physical discomfort (Aaras, Horgen, & Ro, 2000). Therefore, the presence of rest breaks may influence the reduction of static loads for computer operators. Galinsky et al. (2000) reported that physical discomfort was decreased with rest breaks of more than 15 minutes for every half hour of computer work, and other studies (Fisher et al., 1993; Henning et al., 1997) recommended frequent and short breaks of 5 minutes every half hour.

Section 7 – Laptop workstation setup

Laptop workstation setup section (3 items) included information about the typical laptop workstation setup used by students, the severity of physical discomfort experienced while using these typical laptop workstation setups, and the perceived comfortable laptop workstation setups. Respondents were shown a picture of 6 different laptop workstation setups: sitting with laptop on desk, lying prone, lying supine, floor sitting, chair sitting, and sitting with laptop on the lap (see

Figure 3-3). Each respondent assigned a certain percentage of time used to each type of laptop workstation setups, based on a total of 100 percent. Physical discomfort related to each laptop workstation setup was measured by the VAS that is similar in format to the one described in Section 3 (laptop transportation methods).

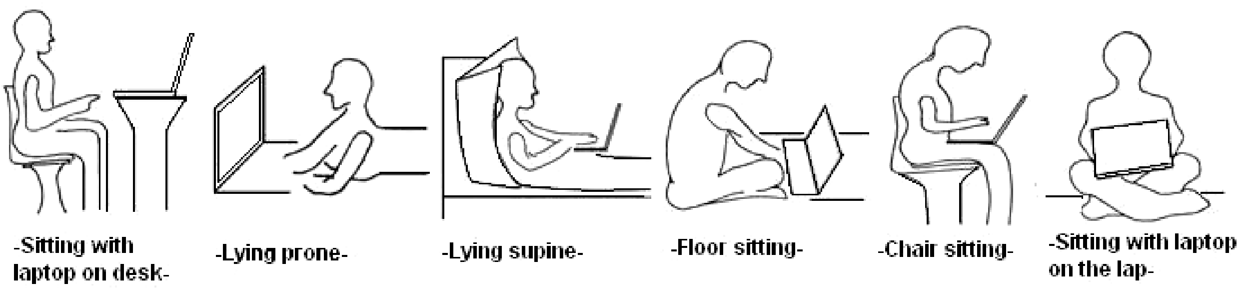


Figure 3-3. Laptop workstation setups adopted in item 7.1 ‘typical laptop workstation setups’

Rationale: Several surveys have reported that laptop computer operators used their laptop computers at various workstation setups, such as desktop sitting (e.g., writing, regular, computer, or sofa tables), lying prone, floor sitting, stool sitting, chair sitting (e.g., sofa, bench, fixed chair, or height-adjustable chair), and lap sitting. These studies suggested that laptop computer operators’ discomfort might be caused by awkward postures assumed in these various non-traditional laptop workstation setups (Harris & Straker, 2000; Raps & Nanthavanij, 2008; Sommerich et al., 2007), supporting the effect of laptop workstation setups on laptop computer operators’ postures. This suggestion is supported by Moffet et al. (2002) and Asunsi et al. (2010), who reported that laptop computer operators showed more neutral body postures (i.e., less head flexion, trunk extension, and wrist extension) and less discomfort in the desktop sitting workstation setup than those in the lap sitting workstation setup.

Section 8 – Overall laptop-related discomfort

Overall laptop-related discomfort section (2 items) included: a filter question and a discomfort rating chart. Before asking the levels of physical discomfort, respondents were asked to indicate if they ever experienced any discomfort during laptop computer use using a dichotomous option (yes or no responses). Respondents who checked ‘yes’ answered the next item which identified the severity of discomfort experienced during laptop computer use (i.e., discomfort rating chart). Respondents who checked ‘no’ skipped to Section 9 (i.e., Student Health Related Role Functioning).

The discomfort rating chart included a combination of a modified Corlett and Bishop’s body chart (Corlett & Bishop, 1976) and the Visual Analogue Scale (VAS). Corlett and Bishop’s body chart is comprised of a pictographic form of the human body with several numbered sections as a means of helping the respondents identify the body area where discomfort is experienced. The original body chart used by Corlett and Bishop (1976) has been adapted by many researchers (Drury et al., 1989; Olendorf & Drury, 2001). The pictograph of human body is divided into individual segments, and numbered according to body regions. It is a valid and reliable instrument (Kumar, Narayan, & Bjornsdottir, 1999). For this study, the pictograph derived from Corlett and Bishop’s body chart was modified. Since this study was interested in examining the discomfort of the upper body, we added an additional element (i.e., hand and wrist) to the body parts labeled in original body chart (see Figure 3-4). Eleven body regions were included in the discomfort rating chart of the LCUSS: neck, right shoulder, left shoulder, right upper arm, left upper arm, right lower arm, left lower arm, right hand/wrist, left hand/wrist, upper back, and lower back. After identifying each body area in the modified

Corlett and Bishop's body chart, respondents determined their level of discomfort severity using the VAS.

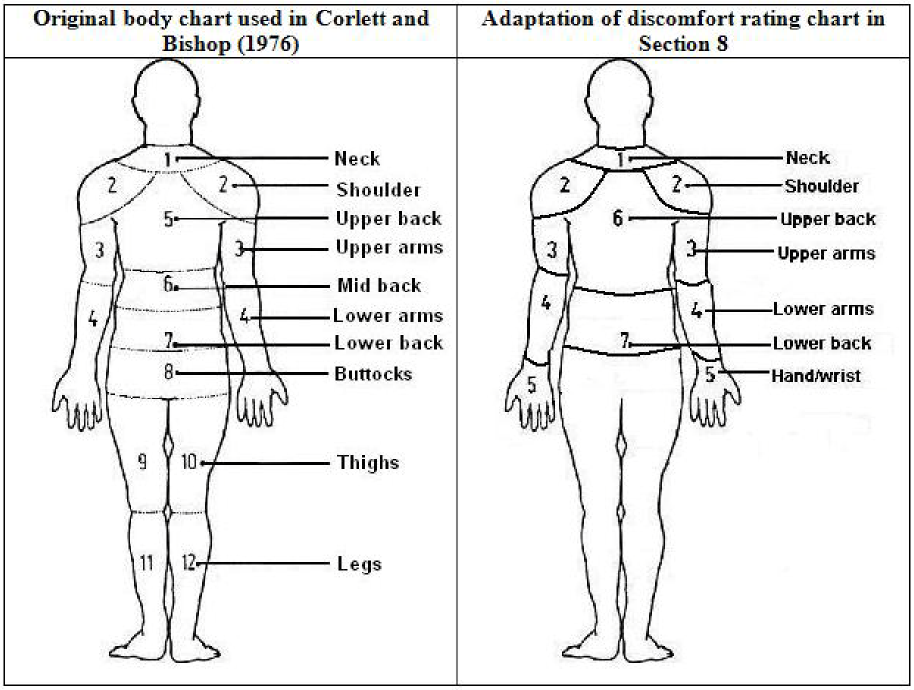


Figure 3-4. Corlett and Bishop's body chart (left) and adaptation in item 8.2 (right)

Rationale: Several studies have found that physical discomfort is prevalent in laptop computer operators (Hamilton et al., 2005; Jacobs et al., 2009; Raps & Nanthavanij, 2008; Straker et al., 1997). In an early survey by Straker and Harris (2000), 60% of laptop computer operators reported physical discomfort during their laptop computer use, and more laptop computer operators experienced discomfort in the neck (> 38%) than in any other body part. This high prevalence of laptop-related discomfort is supported by other survey studies that demonstrated that more than 50% of college students reported physical discomfort related to their laptop computer use. Students also rated high level of discomfort on their neck, shoulder, and back (Jacobs et al., 2009; Raps & Nanthavanij, 2008; Sommerich et al., 2007).

Section 9 – Student health related role functioning

Student health related role functioning section (16 items) measured effects of computer-related MSS on roles experienced by college students. The Student Health Related Role Functioning measure (SHRRF) developed by Katz et al. (2002) consists of 10 items ranging from 0 which represents ‘no difficulty,’ to 4 which represents ‘so difficult I cannot do.’

For the purpose of this study, the original SHRRF was modified. Figure 3-5 shows the original SHRRF and modified version. In addition to the original 9 items in the SHRRF, the tenth item (i.e., ‘do extracurricular activities’) was replaced with 7 recreational items to determine detailed information about type of recreational activities. These 7 items were derived from Section 11 (i.e., recreational activities) in the LCUSS: sports activities; playing a musical instrument; video games; use of mobile phone; laboratory activities; intensive hand related activities; and lifting and carrying activities. Since the original SHRRF was used for desktop computer operators, changing some words were required for this study. Some words, such as ‘computer,’ were changed to ‘laptop computer.’

The SHRRF is internally consistent (Cronbach’s alpha of 0.87) and responsive to self-perceived change (Katz et al., 2002). Katz and colleagues (2002) measured convergent validity by comparing the SHRRF with the Brigham Functional Limitation Scale and with measures of Generic Pain Severity and Brigham Symptom Severity. The results showed high correlations with Brigham Functional Limitation Scale (r = .68), Generic Pain Severity (r = .65), and Brigham Symptom Severity (r = .62).

Original items of SHRRF (Katz et al., 2002)
(a) Type 10 pages (double spaced) on the computer
(b) Complete assignments on the computer (such as typed papers) on time
(c) Do assignments on the computer as well as you would like
(d) Complete handwritten assignments (such as problem sets)
(e) Correspond as often as you would like by email with friends, faculty and others
(f) Take notes in class by hand
(g) Take timed written examinations
(h) Do extracurricular activities (such as sports, musical instruments, hobbies)
(i) Use the mouse (or other computer pointing device) repeatedly
(j) Carry your books around campus

Adaptation in Section 9 of the LCUSS
(1) Type 10 pages (double spaced) on the laptop computer
(2) Complete assignments on the laptop computer (such as typed papers) on time
(3) Do assignments on the laptop computer as well as you would like
(4) Complete handwritten assignments (such as problem sets)
(5) Correspond as often as you would like by email with friends, faculty and others
(6) Take notes in class by hand
(7) Take timed written examinations
(8) Use the mouse (or other laptop computer pointing devices) repeatedly
(9) Carry your books around campus
(10) Sports activities, such as running, lifting weights, participating in sports
(11) Play a musical instrument (piano, guitar, violin, etc.)
(12) Play video games
(13) Use of mobile phones for phoning, playing games, or text messages
(14) Laboratory activities such as using a pipette or soldering iron
(15) Intensive hand related activities (handwriting, sorting books, journals, etc.)
(16) Lifting or carrying groceries, boxes, or books

Figure 3-5. Items of original SHRRF (left) and adaptation in section 9 (right)

Rationale: With the rapid increase of laptop computer use in college students, more students are likely to report physical discomfort while using their laptop computers (Hamilton et al., 2005; Jacobs et al., 2009; Raps & Nanthavanij, 2008). These health problems may affect students' functional roles in academic, social, or personal activities. Hupert et al. (2004) reported that 41% of college students experienced functional limitations in academic and extracurricular activities due to their computer-related discomfort. This finding is also supported by Jenkins et al. (2007) who reported that 62% of college students who had computer-related discomfort experienced upper extremity functional limitations in their academic activities. Among these students, 15% of students reported using health care service (e.g., medical treatment or medication) to relieve their discomfort.

Section 10 – Attitude toward the laptop computer

Attitude toward the laptop computer section (9 items) measured students' positive and negative attitudes towards laptop computers with 5-point Likert-type scale: strongly agree, agree, neutral, disagree, and strongly disagree. There were 5 items which measured positive attitudes and 4 items which measured negative attitudes. These items were extracted from a survey developed by Sommerich et al. (2007). The original version of the survey had a total of 21 items about attitudes towards laptop computers. Although we were interested in college students' attitudes towards their laptop computers, the current study was focused on describing general characteristics of laptop computer use and potential risk factors associated with these characteristics. Therefore, only 9 items (positive and negative effects on academic activities) were used in this section.

Rationale: Students' positive attitudes towards their laptop computers may contribute to more frequent use or greater exposure to the laptop computers (Sommerich et al., 2007; Straker & Pollock, 2005). In a cross-sectional study with high school students by Sommerich et al. (2007), the students' attitudes towards laptop computers were generally positive, suggesting that these positive attitudes may influence increased use of laptop computers.

Section 11 – Recreational activities

Recreational activities section (7 items) measured the amount of time that students spent in seven recreational or non-occupational activities a week. These recreational activities were defined as sports activities, playing a musical instrument, video games, use of mobile phone, laboratory activities, intensive hand related activities, and lifting and carrying activities. Respondents were asked to rate each activity using a 5-point Likert-type scale: never or rarely, up to 5 hours, 6 to 10 hours, 11 to 20 hours, and more than 20 hours.

Rationale: Excessive recreational or non-occupational activities may affect overall fitness as a risk factor for MSD/MSS (Bruno et al., 2008; Gosheger et al., 2003; Green & Rayan, 1997; Marras & Granata, 1995). If students are engaged in recreational activities that require forceful exertion or repetitive movement, these may be risk factors that may be associated with potential MSD/MSS. Several studies found a strong relationship between MSD/MSS and sports (Adams, 1965; Green & Rayan, 1997; Miller et al., 2007), musical activities (Bruno et al., 2008; Hagberg et al., 2005), video or computer games (Johnsson-smaragdi, d'Haenens, & Krotz, 1998; Macgregor, 2000), and mobile phone use (Hocking, 1998).

Section 12 – Previous/current health status

Previous/current health status section (8 items) gathered information regarding pre-existing medical conditions, such as MSD (e.g., muscle spasm or sprain, tendonitis, thoracic outlet syndrome, carpal tunnel syndrome, bursitis etc.), smoking behaviors, vision problems, and overall self-reported physical health. Six items used multiple choice scales to determine respondents' previous or current health status, while the other two items were filter questions in order to direct the respondents to the subsequent questions with dichotomous responses (yes or no responses).

Rationale: Although the purpose of our study was to identify potential risk factors associated laptop-related MSS, the multifactorial nature of MSS require investigation of some individual factors that may be related to MSS. These factors include previous/current history of MSD, cigarette smoking (Hartman, Vrielink, Huirne, & Metz, 2006; Kaergaard & Andersen, 2000), visual correction (Johnston, Souvlis, Jimmieson, & Jull, 2008), and self-perception of general health condition (Kaergaard & Andersen, 2000; Lotters & Burdorf, 2006).

3.2.4.2 Content validation process

After creating the first draft version of the LCUSS (beta-1) based on the literature review, the items and response choices were further expanded and modified through a content validation process with content reviewers. Lynn (1995) has recommended that 3 to 10 content reviewers should be employed to establish the validity of instrument. Developing survey instrument based on a consensus from a panel of content reviewers has been widely documented in the fields of survey research (Binkley, Finch, Hall, Black, & Gowland, 1993; Katz, 2002; Martin, Engelberg, Agel, Snapp, & Swiontkowski, 1996).

This study had two rounds of review by a panel of content reviewers: the first round was conducted by three content reviewers on August 20, 2009; and second round was conducted by two graduate student reviewers on October 12, 2009. Reviewers were given a draft version of the LCUSS (beta-1), and an expert panel evaluation form including guidelines and directions for the panel of reviewers (see Appendix A).

The main points of consideration were: (1) if the questions were clear and understandable; (2) if the examples were clear and appropriate; (3) if the order of questions was clear; (4) if additional questions were needed; and (5) if the general survey design (i.e., font size, length of the survey, and format) was appropriate. Reviewers rated each question item using a dichotomous Yes/No scale and provided comments or suggestions. This procedure provided an opportunity to detect and remedy a wide range of potential problems in the survey instrument.

All reviewers agreed that the 12 topic domains addressed in the LCUSS (beta-1) and content of subsequent items were appropriate, and minor changes of content were needed. Most concerns raised by the reviewers were specific wording problems and survey format flow. For the wording problems, we changed some ambiguous or unclear words. In addition, the reviewers suggested that less important questions should be moved to the end of the survey, and similar questions should always be grouped together. Sections 1 to 8 were kept in their original order, because these domains had the most similar items regarding the characteristics of laptop computer use. Section 9 (previous/current health status) and section 10 (recreational activities) of the original survey were moved to end of survey, because these questions were less important as they addressed individual factors, not laptop-related factors. Additional feedback was that all questions and response choices should be precoded to simplify and speed up the process of entering data into a computer program. Numerical codes, therefore, were provided by the side of each of the response choices. A summary of the suggestions raised by reviewers are described in Appendix B. Based on feedback from a panel of reviewers, the draft version of the LCUSS (beta-1) was modified, revised, and finalized.

3.2.4.3 Test-retest reliability of the LCUSS

Fifteen of 30 subjects who participated in the experimental study (Chapter 4) agreed to take part in the test-retest reliability study. Fleiss (1986) has recommended that minimum of 15 to 20 subjects are required for estimating the reliability of a quantitative variable. Thus, we considered that this sample size was a reasonable number to be confident on the reliability of the results. After finishing the first survey, all subjects were provided with a copy of the LCUSS to take home with them. They were asked to complete the survey two weeks later and return it. Each subject was contacted by the PI by e-mail to complete and return the second survey.

All data were entered into the Microsoft Office Excel 2007 and analyzed by the Statistical Package for the Social Sciences (SPSS) 17.0 software program. Test-retest reliability was assessed by comparing instrument scores for respondents from the 2 time points. Intra-class correlation coefficients (ICCs) were used to calculate the linear correlation of two continuous or percentage variables. ICCs were considered as ‘good’ reliability when above 0.5 or less than 0.8, and excellent if greater than .80 (Hulley, 2007). In this study, we used single measure ICCs because this survey may be only used once by a student at one time period (Yen & Lo, 2002). Kappa statistics were calculated for dichotomous variables (yes or no responses). A Kappa value over 0.75 is considered as ‘excellent’ reliability, 0.40 to 0.75 as ‘good’ reliability, and below 0.40 as ‘poor’ reliability (Fleiss & Cohen, 1973).

Most ICCs were generally ‘acceptable’ or ‘good’ and ranged from 0.53 to 1.00 ($p < .05$), except for one item (i.e., discomfort related to rolling back or brief case) (ICCs = 0.01, $p = .49$). All Kappa coefficients were also significant at ‘good’ to ‘excellent’ level. They ranged from 0.44 to 1.00 ($p < .05$). Only one item showed a ‘poor’ level; item 5.2 (i.e., type of input device related to keyboard) (Kappa = 0.33, $p = .09$). The results of ICCs and Kappa are shown in Appendices C and D, respectively.

The final version of the LCUSS (see Appendix E) was used to describe the characteristics of laptop computer use in college students, and examine the relationships between laptop related factors (i.e., duration of laptop computer use and type of laptop workstation setups) and physical discomfort.

3.2.5 Procedures

This survey study was approved by the University of Pittsburgh Institutional Review Board. After obtaining informed consent, the LCUSS was distributed to 30 students at the University of Pittsburgh. Information regarding inclusion/exclusion criteria was described in Section 3.2.3. Filling out the survey and consent form took an average of 30 minutes and maximum of 50 minutes.

3.2.6 Data management and processing

The raw data from the LCUSS was manually entered into a Microsoft Office Excel 2007 spreadsheet, and then transferred into a SPSS 17.0 software program. The LCUSS includes a total of 75 items with seven types of response scales: multiple-choice (23 items); constant sum (3 items); rank order (3 items); Likert-type (32 items); dichotomous (3 items); textbox (8 items); and visual analogue scales (3 items). Multiple choice scales were used for both single (17 items) and multiple answers (6 items).

3.2.7 Data analyses

Research aim 2: Characteristics of laptop computer use

To answer this research aim, we completed descriptive analyses for all variables. Categorical data were represented using frequencies and percentages. For the continuous data, we calculated means, standard deviations, and ranges.

Research question 3.1: Relationship between duration of laptop computer use and discomfort

Duration of laptop computer use consisted of three items in Section 6 of the LCUSS: (1) length of years having a laptop computer; (2) duration of daily laptop computer use, in minutes; and (3) duration of continuous laptop computer use without breaks, in minutes. Overall laptop-related discomfort scores were obtained from Section 8.2. To compare these time variables with overall laptop-related discomfort, we first calculated the “average discomfort score” by summing all the discomfort scores and dividing by eleven body regions. Pearson’s correlation was used to discover if the continuous time variables were related to the average laptop-related discomfort value. In addition, an independent *t*-test was used to compare time variables between two discomfort groups (minimum discomfort group < 2 cm, and greater than minimum discomfort group ≥ 2 cm). We selected 2 cm as our split point as previous research has suggested that less than 2 cm indicates a minimal level of discomfort. (Oeverland, Akre, Kvaerner, & Skatvedt, 2005). The selected critical level of alpha significance for all tests was $p < .05$.

Research question 3.2: Relationship between laptop workstation setup and discomfort

There were six laptop workstation setups rated on a continuous scale (i.e., percentage) in Section 7.1 of the LCUSS: (1) sitting with laptop on desk; (2) lying prone; (3) lying supine; (4) floor sitting; (5) chair sitting; and (6) sitting with laptop on the lap. We used the same analysis strategy that was described in the research question 3.1. After calculating the average score of overall discomfort, we computed the Pearson's correlation between the average discomfort value and the percentage of time spent in each of the six laptop workstation setups. An independent *t*-test was used to compare percentage of time at each laptop workstation setup between the two discomfort groups (minimum discomfort group < 2 cm, and greater than minimum discomfort group ≥ 2 cm). Statistical significance was set at $p < .05$.

3.3 RESULTS

3.3.1 Research aim 2: Characteristics of laptop computer use

3.3.1.1 Section 1: Demographic information

There were 30 college students in this study, 25 female and 5 male. Table 3-1 shows the demographic characteristics of the sample. Ages ranged from 20 to 48 years with a mean age of 26.0 ± 7.3. The participants' mean height and weight were 70.3 ± 2.7 inches for men and 66.1 ± 5.6 inches for women, and 162.8 ± 35.3 lbs for men and 141.0 ± 32.9 lbs for women. The majority of participants were white (63.3%), right handed (90.0%), never married (86.7%), and full time students (100%).

Table 3-1. Demographic Characteristics of Participants

Demographics	Mean ± SD or number (%)
Age, years	26.0 ± 7.3
Male	28.4 ± 5.2
Female	25.5 ± 7.6
Gender	
Female	25 (83.3%)
Height, in.	66.8 ± 5.4
Male	70.3 ± 2.7
Female	66.1 ± 5.6
Weight, lbs	144.6 ± 33.7
Male	162.8 ± 35.3
Female	141.0 ± 32.9

Table 3–1 (Continued).

Demographics	Mean ± SD or number (%)
Ethnicity	
Non Hispanic or Latino	30 (100.0%)
Race	
Asian	10 (33.3%)
Black or African American	1 (3.3%)
White or Caucasian	19 (63.3%)
Dominant hand	
Right	27 (90.0%)
Left	2 (6.7%)
Both	1 (3.3%)
Marital status	
Never married	26 (86.7%)
Married	2 (6.7%)
Divorced	2 (6.7%)
Current enrollment status	
Full time student	30 (100.0%)
Entrance year into a university, years	2007.0 ± 2.1
Anticipated graduation year, years	2010.0 ± 0.6
Class level	
Sophomore	1 (3.3%)
Junior	6 (20.0%)
Senior	6 (20.0%)
Graduate students	17 (56.7%)
Residence classification at the university	
In-state student	16 (53.3%)
Out-of-state student	3 (10.0%)
International student	11 (36.7%)

3.3.1.2 Section 2: Location of laptop computer use

The most popular location of laptop computer use was home (69.7 ± 31.3%), followed by library (9.8 ± 16.0%), café or restaurant (8.4 ± 20.9%), and campus classroom (4.2 ± 10.0%) (see Table 3-2). More than 20% of respondents reported that their primary reason (1^{st} and 2^{nd} most important) for location selection was accessibility of wireless internet, followed by presence of electrical outlet and convenient location (See Table 3-3).

Table 3-2. Location Percentages for Laptop Computer Use (Item 2.1)

Locations of laptop computer use	Mean ± SD (%)
Home (*n* = 27)	69.7 ± 31.3
Library (*n* = 17)	9.8 ± 16.0
Café or restaurant (*n* = 11)	8.4 ± 20.9
Campus classroom (*n* = 10)	4.2 ± 10.0
Office (*n* = 2)	3.0 ± 11.5
Outdoor places (yarn, lawn, street) (*n* =5)	2.3 ± 9.2
Campus computer lab (*n* = 6)	1.8 ± 3.8
Friend’s house (*n* = 2)	0.5 ± 2.0
Transportation (in bus, car, or plane) (*n* = 2)	0.2 ± 1.0

Note. ‘*n*’ indicates the number of respondents who selected each response, as ‘yes’

Table 3-3. Frequency of Reason for Location Selection (Item 2.2)

Selection Reasons	1st important	2nd important	3rd important	4th important	5th important	6th important	N/A
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
Accessibility of wireless internet	10 (33.3)	8 (26.7)	6 (20.0)	5 (16.7)	1 (3.3)	-	-
Presence of electrical outlet	7 (23.3)	6 (20.0)	8 (26.7)	6 (20.0)	3 (10.0)	-	-
Presence of chair and desk	4 (13.3)	5 (16.7)	7 (23.3)	7 (23.3)	5 (16.7)	1 (3.3)	1 (3.3)
Presence of comfortable chair	-	6 (20.0)	2 (6.7)	4 (13.3)	14 (46.7)	2 (6.7)	2 (6.7)
Location is convenient	7 (23.3)	6 (20.0)	7 (23.3)	5 (16.7)	4 (13.3)	-	1 (3.3)
Laptop size and weight	2 (6.7)	-	-	-	-	1 (3.3)	27 (90.0)

Note. N/A = Not applicable; Total number of respondents (*N* = 30) are defined as the horizontal sum

3.3.1.3 Section 3: Laptop transportation methods

Most respondents carried their laptop computers in their backpacks (76.7%) and in the shoulder bag (63.3%) (see Table 3-4). While the backpack showed a relatively low discomfort level on the VAS, the shoulder bag showed the highest discomfort level (see Table 3-5). Few respondents used the rolling bag to carry their laptop computers. Most respondents (83.3%) reported that they carried an AC adapter with their laptop computers. Approximately half of the respondents took an external mouse and one-fourth of the respondents took an external battery when carrying their laptop computers (see Table 3-6).

Table 3-4. Frequency of the Carrying Methods of Laptop Computer (Item 3.1)

Carrying methods	*n* (%)
In your backpack	23 (76.7)
Over the shoulder bag or briefcase	19 (63.3)
Bag or briefcase with handle	10 (33.3)
Rolling bag or briefcase	1 (3.3)

Note. '*n*' indicates the number of respondents who selected each response, as 'yes'

Table 3-5. Discomfort Related to Laptop Transportation Methods (Item 3.3)

Discomfort (VAS)	Mean ± SD (cm)
In your backpack (n = 24[a])	2.8 ± 1.6
Over the shoulder bag or briefcase (n = 20[a])	4.1 ± 1.9
Bag or briefcase with handle (n = 12[a])	3.4 ± 2.6
Rolling bag or briefcase (n = 3[a])	1.0 ± 1.2

Note. VAS = visual analogue scale; 'n' indicates the number of respondents who selected each response, as 'yes'; [a]exclude N/A numbers from total 30 respondents. These numbers do not agree with those in the Table 3-4, because some non-respondents for Item 3.1 rated discomfort in Item 3.3

Table 3-6. Frequency of the Carrying External Devices (Item 3.2)

Carrying devices	*n* (%)
AC adapter	25 (83.3)
External mouse (full or small size mice)	13 (43.3)
External battery	7 (23.3)
Extension cord	4 (13.3)
External disk drive	3 (10.0)
External keyboard	-

Note. '*n*' indicates the number of respondents who selected each response, as 'yes'

3.3.1.4 Section 4: Laptop related tasks

Overall, laptop computers were used for several activities, excepting 'check the news, weather, sports, etc.' activity which was not chosen by any respondents. The majority of respondents reported that the most frequently performed task (1^{st} frequent) was to check e-mail (50.0%), followed by word processing (26.7%), and CourseWeb or online course (10.0%) (see Table 3-7). Their second most frequent task was word processing (30.0%), CourseWeb or online course (20.0%), web surfing (16.7%), and communication with others (13.3%). Most respondents tended to do the academic-related tasks (e.g., word processing or CourseWeb) with their laptop computers rather than non-occupational tasks (e.g., play games, pay bills, watch movies, or shopping).

Table 3-7. Frequency of Task Types with Laptop Computer (Item 4.1)

Tasks	1^{st} frequent	2^{nd} frequent	3^{rd} frequent	N/A
	n (%)	*n* (%)	*n* (%)	*n* (%)
Word processing	8 (26.7)	9 (30.0)	9 (30.0)	4 (13.3)
Presentations	-	-	1 (3.3)	29 (96.7)
Analysis or spreadsheets	1 (3.3)	-	2 (6.7)	27 (90.0)
CourseWeb or online courses	3 (10.0)	6 (20.0)	3 (10.0)	18 (60.0)
Library search	-	-	1 (3.3)	29 (96.7)
Web surfing	1 (3.3)	5 (16.7)	3 (10.0)	21 (70.0)
Scheduling	-	1 (3.3)	-	29 (96.7)
Look up contacts	-	-	1 (3.3)	29 (96.7)
Communication with others	2 (6.7)	4 (13.3)	3 (10.0)	21 (70.0)
Shopping	-	1 (3.3)	1 (3.3)	28 (93.3)
Check news, weather, sports, etc.	-	-	-	30 (100.0)
Check e-mail	15 (50.0)	4 (13.3)	3 (10.0)	8 (26.7)
Watch movies or videos	-	-	1 (3.3)	29 (96.7)
Pay bills	-	-	1 (3.3)	29 (96.7)
Play games	-	-	1 (3.3)	29 (96.7)

Note. N/A = Not applicable; '*n*' indicates the number of respondents who selected each response, as 'yes'; Total number of respondents (*N* = 30) are defined as the horizontal sum

3.3.1.5 Section 5: Laptop specifications

The most popular laptop computer model was HP, followed by Dell, and then Lenovo. The mouse (70.0%) and keyboard (63.3%) were the most popular input devices used by respondents. More than half of the respondents used a webcam and speaker. Most respondents owned a laptop computer with a monitor size of 14.0 – 15.9 inches and a weight of 5.0 – 6.9 lbs. (i.e., thin and light type). None of the respondents reported that they used the mini-laptop computers with a monitor size of less than 12 inches and a weight of less than 2.5 lbs. (see Table 3-8).

Table 3-8. Frequency of the Laptop Specifications (Item 5.1; 5.2; 5.3; 5.4; 5.5)

Laptop specifications	*n* (%)
5.1 Laptop computer models	
HP	9 (30.0)
Dell	8 (26.7)
Lenovo (IBM)	5 (16.7)
Toshiba	3 (10.0)
Apple Mac	2 (6.7)
Sony	1 (3.3)
Spartan	1 (3.3)
Jetta	1 (3.3)
5.2 Input devices	
Mouse	21[a] (70.0)
Keyboard	19[a] (63.3)
Touch pad	18[a] (60.0)
Numeric pad	3[a] (10.0)
Trackball	2[a] (6.7)
Track point	1[a] (3.3)
Joystick	-

Table 3–8 (Continued).

Laptop specifications	*n* (%)
5.3 Other external devices	
Speakers	16[a] (53.3)
Webcam	15[a] (50.0)
Microphones	9[a] (30.0)
Earphones	2[a] (6.7)
5.4 Laptop weight	
5.0 – 6.9 Ibs. (Thin and light)	15 (50.0)
2.6 – 4.9 Ibs. (Ultraportable)	8 (26.7)
7.0 Ibs. Or more (Desktop replacement)	7 (23.3)
Less than 2.5 Ibs. (Netbook or subnotebook)	-
5.5 Monitor size	
14.0 – 14.9 inches	9 (30.0)
15.0 – 15.9 inches	9 (30.0)
13.0 – 13.9 inches	6 (20.0)
17.0 inches or more	3 (10.0)
12.0 – 12.9 inches	2 (6.7)
16.0 – 16.9 inches	1 (3.3)
Less than 12.0 inches	-

Note. [a]indicates the number of respondents who selected each response, as 'yes'

3.3.1.6 Section 6: Usage time

Respondents were more likely to use their laptop computers (78.6 ± 22.7%) than their desktop computers (21.4 ± 22.7%) (see Table 3-9). On average, duration of daily laptop computer use was 246.7 ± 161.5 minutes, and duration of continuous laptop computer use without any rest breaks was 92.2 ± 58.2 minutes (see Table 3-10). One-third of the respondents reported that they took rest breaks of less than 5 minutes during laptop computing. Only 5 respondents had a rest break of more than 20 minutes (see Table 3-11).

Table 3-9. Percentages of Weekly Computing Time (Item 6.1)

Weekly computing time	Mean ± SD (%)	Range
Laptop computing time (*n* = 30)	78.6 ± 22.7	20 – 100
Desktop computing time (*n* = 24)	21.4 ± 22.7	0 – 80

Note. ‘*n*’ indicates the number of respondents who selected each response, as ‘yes’

Table 3-10. Duration of Laptop Computer Use (Item 6.2; 6.3; 6.4)

Duration of laptop computer use	Mean ± SD
Length of years having a laptop computer	4.4 ± 2.6
Duration of daily laptop computer use, minutes	246.7 ± 161.5
Duration of continuous laptop computer use, minutes	92.2 ± 58.2

Table 3-11. Frequency of the Typical Rest Breaks (Item 6.5)

Rest breaks	*n* (%)
< 5 minutes	10 (33.3)
5 – 10 minutes	9 (30.0)
11 – 15 minutes	6 (20.0)
26 – 30 minutes	2 (6.7)
> 30 minutes	2 (6.7)
21 – 25 minutes	1 (3.3)
16 – 20 minutes	-
None	-

3.3.1.7 Section 7: Laptop workstation setup

The most common laptop workstation setups used by respondents were sitting with the laptop on a desk (59.3 ± 34.0%), followed by lying supine, chair sitting, lap sitting, floor sitting, and lying prone (see Table 3-12). Most respondents reported high levels of discomfort while lying prone (5.1 ± 2.6 cm) and floor sitting (5.1 ± 1.4 cm) (see Table 3-13). Respondents also reported that they considered the most comfortable laptop workstation setup to be desktop sitting, followed by lying supine, lap sitting, and lying prone. (see Table 3-14).

Table 3-12. Percentage of Time in Each Laptop Computer Workstation Setup (Item 7.1)

Laptop workstation setup	Mean ± SD (%)
Sitting with laptop on desk (n = 27)	59.3 ± 34.0
Lying supine (n = 23)	14.3 ± 16.9
Chair sitting (n = 16)	10.7 ± 21.4
Sitting with laptop on the lap (n = 12)	10.7 ± 22.6
Floor sitting (n = 10)	3.5 ± 7.9
Lying prone (n = 5)	1.4 ± 4.1

Note. ‘*n*’ indicates the number of respondents who selected each response, as ‘yes’

Table 3-13. Discomfort Related to Laptop Workstation Setup (Item 7.2)

Discomfort (VAS)	Mean ± SD (cm)
Sitting with laptop on desk (n = 27[a])	1.9 ± 1.4
Lying supine (n = 23[a])	3.7 ± 1.9
Chair sitting (n = 19[a])	3.7 ± 2.1
Sitting with laptop on the lap (n = 15[a])	3.9 ± 1.9
Floor sitting (n = 12[a])	5.1 ± 1.4
Lying prone (n = 9[a])	5.1 ± 2.6

Note. VAS = visual analogue scale; ‘*n*’ indicates the number of respondents who selected each response, as ‘yes’; [a]exclude N/A numbers from total 30 respondents. These numbers do not agree with those in the Table 3-12, because some non-respondents for Item 7.1 rated discomfort in Item 7.2

Table 3-14. Frequency of Comfortable Workstation Setup for Laptop Computer Use (Item 7.3)

Comfortable workstation setup	1st comfort	2nd comfort	3rd comfort	4th comfort	5th comfort	6th comfort	N/A
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
Sitting with laptop on desk	24 (80.0)	1 (3.3)	3 (10.0)	-	-	2 (6.7)	-
Lying prone	1 (3.3)	1 (3.3)	3 (6.7)	3 (10.0)	4 (13.3)	14 (46.7)	5 (16.7)
Lying supine	3 (10.0)	10 (33.3)	6 (20.0)	4 (13.3)	4 (13.3)	-	3 (10.0)
Floor sitting	-	1 (3.3)	3 (10.0)	8 (26.7)	6 (20.0)	6 (20.0)	6 (20.0)
Chair sitting	-	12 (40.0)	8 (26.7)	5 (16.7)	3 (10.0)	-	2 (6.7)
Sitting with laptop on the lap	2 (6.7)	4 (13.3)	6 (20.0)	5 (16.7)	7 (23.3)	1 (3.3)	5 (16.7)

Note. N/A = Not applicable; Total number of students (N = 30) are defined as the horizontal sum

3.3.1.8 Section 8: Overall laptop related discomfort

Respondents were asked if they experienced any physical discomfort while using their laptop computers. Most respondents (96%) reported neck discomfort, which also had the highest level of discomfort (4.3 ± 2.8 cm) (see Table 3-15). The least frequently reported body areas for discomfort were left lower arm (1.0 ± 1.1 cm) and right (1.2 ± 1.8 cm) and left upper arm (0.9 ± 1.4 cm). Neck and upper back areas experienced the most severe discomfort when using the laptop computers, while left upper arm experienced the least. All right body parts experienced greater discomfort compared to left body parts.

Table 3-15. Overall Discomfort Related to Laptop Computer Work (Item 8.2) (N = 28[a])

Discomfort (VAS)	Mean ± SD (cm)
Neck (*n* = 27)	4.3 ± 2.8
Upper back (*n* = 26)	4.3 ± 2.5
Lower back (*n* = 26)	3.2 ± 2.5
Rt. shoulder (*n* = 21)	2.5 ± 2.8
Lt. shoulder (*n* = 21)	2.2 ± 2.8
Rt. hand/wrist (*n* = 25)	2.2 ± 2.2
Lt. hand/wrist (*n* = 24)	1.8 ± 2.0
Rt. lower arm (*n* = 21)	1.3 ± 1.5
Rt. upper arm (*n* = 20)	1.2 ± 1.8
Lt. lower arm (*n* = 19)	1.0 ± 1.1
Lt. upper arm (*n* = 20)	0.9 ± 1.4

Note. VAS = visual analogue scale; Rt. = Right; Lt. = Left; [a]Two respondents reported no discomfort during laptop computing; '*n*' indicates the number of respondents who selected each response, as 'yes'

3.3.1.9 Section 9: Student health related role functioning

Respondents were asked to rate their health-related functional limitations associated with use of laptop computers. Their responses to these questions are described in Table 3-16. None of the respondents reported that they had maximum difficulty (i.e., so difficult I cannot do at all) in any activity. In general, more than half of the respondents reported 'no difficulty' on most activities. At the individual activity level, most respondents reported 'severe difficulty' and 'mild difficulty' for carrying books around campus, 'moderate difficulty' for taking timed written examinations, and 'no difficulty' for using mobile phones. The 'carrying books around campus' activity was the most frequently mentioned activity associated with functional limitations experienced by respondents with upper extremity discomfort. More than 30% of respondents reported some degree of functional limitations in following items: type 10 pages on the laptop, carry books around campus, and sports activities.

Table 3-16. Frequency of Difficult Activities Related to Discomfort (Item 9.1)

Activities	No difficulty	Mild difficulty	Moderate difficulty	Severe difficulty	So difficult*	N/A
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
Type 10 pages on the laptop	7 (23.3)	7 (23.3)	3 (10.0)	-	-	13 (43.3)
Complete assignments on the laptop on time	21 (70.0)	5 (16.7)	1 (3.3)	1 (3.3)	-	2 (6.7)
Do assignments on the laptop as well as you would like	19 (63.3)	7 (23.3)	2 (6.7)	-	-	2 (6.7)
Complete handwritten assignments	19 (63.3)	5 (16.7)	2 (6.7)	1 (3.3)	-	3 (10.0)
Correspond as often as you would like by email	25 (83.3)	2 (6.7)	3 (10.0)	-	-	-
Take notes in class by hand	19 (63.3)	5 (16.7)	3 (10.0)	1 (3.3)	-	2 (6.7)
Take timed written examinations	19 (63.3)	1 (3.3)	5 (16.7)	2 (6.7)	-	3 (10.0)
Use the mouse repeatedly	24 (80.0)	5 (16.7)	1 (3.3)	-	-	-
Carry books around campus	10 (33.3)	14 (46.7)	3 (10.0)	3 (10.0)	-	-
Sports activities	14 (46.7)	10 (33.3)	3 (10.0)	1 (3.3)	-	2 (6.7)
Play a musical instrument	10 (33.3)	1 (3.3)	1 (3.3)	-	-	18 (60.0)
Play video games	13 (43.3)	1 (3.3)	1 (3.3)	-	-	15 (50.0)
Use of mobile phones	26 (86.7)	2 (6.7)	1 (3.3)	1 (3.3)	-	-
Laboratory activities	14 (46.7)	-	-	-	-	16 (53.3)
Intensive hand related activities	25 (83.3)	3 (10.0)	1 (3.3)	-	-	1 (3.3)
Lifting or carrying groceries, boxes, or books	16 (53.3)	1 (33.3)	2 (6.7)	2 (6.7)	-	-

Note. N/A = Not applicable; Total number of respondents (N = 30) are defined as the horizontal sum; *so difficult I cannot do it at all

3.3.1.10 Section 10: Attitude toward the laptop computer

Table 3-17 provides the respondents' attitudes towards laptop computers. In general, respondents had positive attitudes towards their laptop computers. For the three of five items which addressed positive aspects of laptop computers (i.e., 'make university easier,' 'make university enjoyable,' and 'help interact with others'), more than 40.0% of the respondents chose 'strongly agree.' Respondents chose neutral responses (46.7%) for other two positive items (i.e., 'make notes easier during class' and 'organize class notes easily'). Most respondents did not agree with negative aspects towards their laptop computers, excepting 'a laptop is a distraction in class' item which was rated as neutral response.

Table 3-17. Frequency of the Attitude Toward the Laptop Computer (Item 10.1)

Attitudes	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
Positive attitude					
A laptop makes university easier	22 (73.3)	6 (20.0)	2 (6.7)	-	-
A laptop makes university more enjoyable	14 (46.7)	10 (33.3)	6 (20.0)	-	-
A laptop helps me interact with other students	13 (43.3)	9 (30.0)	5 (16.7)	2 (6.7)	1 (3.3)
It is easier for me to take notes during class with my laptop	2 (6.7)	2 (6.7)	14 (46.7)	9 (30.0)	3 (10.0)
I can organize my class notes easily with my laptop	3 (10.0)	7 (23.3)	14 (46.7)	4 (13.3)	2 (6.7)

Table 3–17 (Continued).

Attitudes	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
Negative attitude					
A laptop is a distraction in class	3 (10.0)	10 (33.3)	12 (40.0)	4 (13.3)	1 (3.3)
I rarely use my laptop	-	2 (6.7)	1 (3.3)	7 (23.3)	20 (66.7)
I do not enjoy using my laptop	-	2 (6.7)	3 (10.0)	6 (20.0)	19 (63.3)
I am often frustrated with my laptop	1 (3.3)	3 (10.0)	5 (16.7)	7 (23.3)	14 (46.7)

Note. Total number of respondents (*N* = 30) are defined as the horizontal sum

3.3.1.11 Section 11: Recreational activities

Table 3-18 provides information regarding respondents' recreational or leisure activities in hours per week. More than 40% of respondents spent less than 5 hours per week in four recreational activities (i.e., lifting or carrying groceries, boxes, or books; intensive hand activities; sports; and use of mobile phone). Three-fourths of the respondents reported that they did not spend time on the other three activities (i.e., play a musical instrument, play video games, and laboratory activities). Thirteen respondents used their mobile phone for more than 6 hours and less than 20 hours per day.

Table 3-18. Frequency of the Recreational Activities (Item 11.1)

Recreational activities	< 5 hours	6-10 hours	11-20 hours	> 20 hours	Never
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
Sports activities	14 (46.7)	6 (20.0)	3 (10.0)	-	7 (23.3)
Play a musical instrument	3 (10.0)	-	-	-	27 (90.0)
Play video games	4 (13.3)	-	-	1 (3.3)	25 (83.3)
Use a mobile phone	13 (43.3)	9 (30.0)	1 (3.3)	3 (10.0)	4 (13.3)
Laboratory activities	4 (13.3)	2 (6.7)	-	-	24 (80.0)
Intensive hand activities	16 (53.3)	4 (13.3)	6 (20.0)	1 (3.3)	3 (10.0)
Lifting or carrying groceries, boxes, or books	22 (73.3)	2 (6.7)	-	-	6 (20.0)

Note. Total number of respondents (N = 30) are defined as the horizontal sum

3.3.1.12 Section 12: Previous/current health status

With regard to previous/current health status, only 7 respondents reported that they were diagnosed or treated by a physician due to musculoskeletal discomfort in their upper body. Most frequently reported diagnosis was lower back pain (20%), followed by muscle spasm and pinched nerve (6.7% for both diagnoses). In this sample, no one was a current smoker. Of 30 respondents, 46.7% had corrected vision with contact lenses (46.7%), followed by glasses and surgery (13.3% for both of them). Most respondents described that their physical health condition was good (60.0%), and at the same level as last year (56.7%). None of the respondents reported that they currently had a poor health condition or that their health was much worse than one year ago (see Table 3-19).

Table 3-19. Frequency of the Previous/Current History (Item 12.1 to 12.8)

Previous/current health status	*n* (%)
History of medical diagnosis	
Yes	7 (23.3)
Type of musculoskeletal disorders	
Lower back pain	6 (20.0)
Muscle spasm or sprain	2 (6.7)
Pinched nerve	2 (6.7)
Ruptured or herniated disk in back	1 (3.3)
Tenosynovitis	1 (3.3)
Smoke cigarettes	
No	30 (100.0)
Vision correction	
Corrected with contact lenses	14 (46.7)
Uncorrected vision	8 (26.7)
Corrected with glasses	4 (13.3)
Corrected with surgery	4 (13.3)
Perceived overall physical health condition	
Good	18 (60.0)
Excellent	8 (26.7)
Fair	4 (13.3)
Poor	-
Comparison to the last year for the overall physical health	
About the same as one year ago	17 (56.7)
Somewhat better now than one year ago	8 (26.7)
Somewhat worse now than one year ago	5 (16.7)
Much better now than one year ago	-
Much worse now than one year ago	-

Note. '*n*' indicates the number of respondents who selected each response, as 'yes'

3.3.2 Research question 3.1: Relationship between duration of laptop computer use and discomfort

No significant correlations between duration of laptop computer use (i.e., length of years having a laptop computer, duration of daily laptop computer use, and duration of continuous laptop computer use) and average laptop-related discomfort were found (see Table 3-20). We completed *post-hoc* scatter plots to assess if there was a non-linear relationship between duration and discomfort. These scatter plots also showed no apparent non-linear relationships between duration of laptop use and average laptop-related discomfort (see Appendix H) There were no significant differences for duration of laptop computer use between the two discomfort groups, but the discomfort group (i.e., greater than minimum discomfort ≥ 2cm) tended to spend more continuous time on laptop computer use (see Table 3-21).

Table 3-20. Relationship Between Duration of Laptop Computer Use and Average Laptop-Related Discomfort

Duration of laptop computer use	*r*	*p*
Length of years having a laptop computer	.11	.56
Duration of daily laptop computer use, minutes	.16	.39
Duration of continuous laptop computer use, minutes	.24	.20

Note. r = Pearson’s correlation

Table 3-21. Independent *t*-test of Duration of Laptop Computer Use Between Discomfort Groups

Duration	Discomfort groups	*n*	Mean ± SD	*t*	*df*	*p*
Length of years	Min. (< 2 cm)	18	4.3 ± 1.6	-.09	28	.93
	Greater than Min.(≥ 2 cm)	12	4.4 ± 3.6			
Duration of daily laptop computer use, minutes	Min. (< 2 cm)	18	232.8 ± 159.1	-.57	28	.57
	Greater than Min. (≥ 2 cm)	12	267.5 ± 169.9			
Duration of continuous laptop computer use, minutes	Min. (< 2 cm)	18	79.7 ± 44.1	-1.46	28	.15
	Greater than Min. (≥ 2 cm)	12	110.8 ± 72.6			

Note. Min. = Minimum

3.3.3 Research question 3.2: Relationship between laptop workstation setups and discomfort

There was no significant relationship between time spent (%) in the various laptop workstation setups (i.e., desktop sitting, lying prone, lying supine, floor sitting, chair sitting, and lap sitting) and average laptop-related discomfort (see Table 3-22). In a similar fashion to Reseach question 3.1 a scatter plot showed no apparent non-linear relationships between percentage of time spent in a laptop workstation setup and average laptop-related discomfort (see Appendix I). The results were not significantly different between the two groups (see Table 3-23).

Table 3-22. Relationship Between Percentage of Time Spent in a Laptop Workstation Setup and Average Laptop-Related Discomfort

Laptop workstation setup	*r*	*p*
Desktop sitting	.04	.82
Lying prone	.02	.92
Lying supine	.10	.62
Floor sitting	.29	.13
Chair sitting	-.14	.47
Lap sitting	-.11	.57

Note. *r* = Pearson's correlation

Table 3-23. Independent *t*-test of Percentage of Time Spent in a Laptop Workstation Setups Between Two Discomfort Groups

Laptop workstation setups	Discomfort groups	*n*	Mean ± SD	*t*	*df*	*p*
Desktop sitting, %	Min. (< 2 cm)	18	52.8 ± 37.8	-1.31	28	.20
	Greater than Min. (≥ 2 cm)	12	69.2 ± 25.8			
Lying prone, %	Min. (< 2 cm)	18	1.6 ± 4.8	0.39	28	.70
	Greater than Min. (≥ 2 cm)	12	1.0 ± 2.9			
Lying supine, %	Min. (< 2 cm)	18	16.1 ± 19.9	0.73	28	.47
	Greater than Min. (≥ 2 cm)	12	11.5 ± 11.3			
Floor sitting, %	Min. (< 2 cm)	18	2.2 ± 4.3	-1.05	28	.30
	Greater than Min. (≥ 2 cm)	12	5.3 ± 11.5			
Chair sitting, %	Min. (< 2 cm)	18	14.7 ± 26.7	1.27	28	.21
	Greater than Min. (≥ 2 cm)	12	4.7 ± 6.4			
Lap sitting, %	Min. (< 2 cm)	18	12.3 ± 24.4	0.46	28	.65
	Greater than Min. (≥ 2 cm)	12	8.3 ± 20.4			

Note. Min. = Minimum

3.4 DISCUSSION

Our first aim for this study was to develop a valid and reliable survey instrument (Laptop Computer User Screening Survey [LCUSS]) to characterize laptop computer-use patterns and to examine the relationships between laptop computer use and physical discomfort. The content validation process supported the content and structure of the items in the LCUSS. Although some wording and design problems were raised by the reviewers, these problems were modified, and it was determined that the LCUSS had valid content and an adequate design format to identify laptop computer use in college students and factors associated with discomfort.

The LCUSS demonstrated overall good test-retest reliability, suggesting that survey results are consistent over two test administrations with a time interval of 14 days. Only two items showed poor reliability: 'discomfort related to rolling back or brief case' and 'type of input device related to keyboard.' For the 'discomfort related to rolling back or brief case,' there were only 3 respondents who reported discomfort, and all the levels were lower at the second survey compared with levels at the first survey. These respondents may have underestimated their discomfort levels on the second survey, because this carrying method was rarely used. For the 'input device related to the keyboard,' 5 respondents who reported 'no use of keyboard' at the first survey changed their responses to 'use of keyboard.' This change may have been caused by a misunderstanding of the term 'input device.' During the first survey, many respondents asked if keyboard was a type of input device, indicating confusion of this term. In addition, while rating discomfort associated with carrying a laptop computer, some respondents misunderstood the question. For example, although some respondents reported non-use of their backpacks to transport their laptop computers, they rated discomfort associated with their backpacks on the VAS. The LCUSS should be modified to address these unclear wording problems.

The test-retest agreement for discomfort rated using the 10-cm VAS also had relatively low reliability coefficients compared with other items. Respondents were asked to rate their discomfort based on their symptoms at the time of the survey. Since physical discomfort can easily fluctuate over time, it is likely that respondents had slightly different severity of discomfort after 14 days. The LCUSS should be modified a term of 'current symptom' to 'average symptom over some period.'

The second aim of our study was to identify the characteristics of laptop computer use in college students. The results indicate that respondents tended to use their laptop computers in a variety of locations without appropriate environmental equipment (e.g., desks, chairs, or external devices), The most popular location was home, followed by library, café or restaurant,. The type of laptop workstation setups used by this sample was also varied, and the most common workstation setup was desktop sitting, followed by lying supine, chair sitting, lap sitting, and floor sitting, and lying prone. This variability of location for laptop computer use may place laptop computer operators at more risk than desktop computer operators who usually work in traditional computer workstation setups with a desk and a chair, because laptop computer operators may assume awkward body postures in various environments without appropriate supports (Harris & Straker, 2000; Moffet et al., 2002; Raps & Nanthavanij, 2008). In addition, most respondents reported that they selected their location of laptop computer use based on laptop-related technical supports (e.g., accessibility of wireless internet or presence of electrical outlet), rather than environmental adequacy (e.g., presence of desk, table, or chair). This suggests that public place with wireless internet set-up should be well furnished with desk, chair, and electrical outlet to facilitate optimal workstation setup.

A lack of understanding of environmental adequacy may lead laptop computer operators to assume a greater variety of awkward postures when using their laptop computers. If laptop computer operators maintain these awkward postures for long periods of time, they may be at greater risk for getting MSD/MSS than those who work in traditional computer workstation setups with appropriate environmental supports (Harris & Straker, 2000; Moffet et al., 2002; Raps & Nanthavanij, 2008; Sommerich et al., 2007). Several research studies have reported that non-traditional laptop workstation setups which allow laptop computer operators to assume awkward postures may cause physical discomfort (Harris & Straker, 2000; Raps & Nanthavanij, 2008; Sommerich et al., 2007). In our study, most respondents experienced the least discomfort in the traditional laptop workstation setup (i.e., desktop sitting) compared to the other laptop workstation setups.

Our respondents reported that they used their laptop computers for approximately 1 ½ hours without any rest breaks, and spent an average of 4 hr/day on their laptop computers. Prolonged computer use without appropriate rest breaks has been recognized as a predominant risk factor for MSD/MSS (Carter & Banister, 1994; Schlossberg et al., 2004). Desktop computer work of greater than 4-5 hr/day are considered to place computer operators at risk (Chang et al., 2007; Schlossberg et al., 2004), and research studies recommend that computer operators should take frequent and short breaks of 5 minutes every half hour to prevent the onset of discomfort (Fisher et al., 1993; Henning et al., 1997). Our respondents reported that they spent more time with their laptop computers (78.6% per week), than desktop computers (21.4% per week), suggesting that respondents may be at greater risk for developing MSD/MSS.

Although the most frequently performed task with laptop computer was to check e-mail, more respondents performed word processing tasks related to their academic assignments than any other task. These keyboard intensive tasks (i.e., word-processing task) may require more dynamic and repetitive movements of the upper extremities, compared with the mouse clicking tasks (i.e., checking e-mail or news, web surfing, or paying bills). Dennerlein and Johnson (2006) demonstrated that keyboard intensive tasks were associated with more postural variability and muscle activity in the upper extremities. Therefore, our sample may have greater chances of awkward postures in their keyboard intensive tasks, particularly if it continues for long periods of time. All these findings suggest that laptop computer use is positively associated with potential risk factors for MSS, and future studies should be done to confirm laptop-related risk factors and to establish best laptop workstation setup to minimize these risk factors.

The most common areas for discomfort reported by the respondents while using their laptop computers were the neck and upper back. Since previous research studies have reported a high prevalence of neck and shoulder discomfort in laptop computer operators (Harris & Straker, 2000; Sommerich et al., 2007; Straker et al., 1997), we had assumed that respondents would experience greater discomfort in their necks and shoulders. However, our respondents experienced relatively less discomfort in their shoulders than their necks. This difference may be caused by confusion as to the precise body area designated as 'shoulder.' Neck, shoulder, and upper back are connected together by the trapezius muscle that extends vertically form occipital bone to thoracic vertebrae and laterally from spine to acromion process (Oatis, 2009). If respondents felt discomfort between the lowermost portion of neck and shoulder blade (i.e., upper portion of the trapezius), they may have identified this as the upper back discomfort rather than the shoulder discomfort.

Respondents experienced the most severe discomfort when carrying a laptop computer in a shoulder bag (66.6%) and the least when using a backpack (76.7%). The use of a two strap backpack may spread the loading weight more evenly, compared with a shoulder bag with one strap. These results highlight the importance of choice of laptop carrying methods. Most respondents (83.3%) also reported that they carried an AC adapter with their laptop computers. This additional weight may increase physical discomfort while carrying a laptop computer, because the weight of some AC adaptors is more than 2 pounds. If respondents added other supplementary devices (e.g., external battery or extension cord) in their carrying bag, this could also increase the risks for discomfort. Although other research studies (Harris & Straker, 2000; Sommerich et al., 2007) have reported similar results, that shoulder discomfort is frequently cited by laptop computer operators while carrying their laptop computers, these studies did not measure the severity of discomfort associated with the type of carrying methods. Overall, the method of carrying a laptop computer appears to be a potential risk factor for neck and upper back discomfort. Future studies are needed to confirm the best method of carrying a laptop computer, and finding a balance between portability (i.e., small and light laptop devices). Reducing awkward postures related to the small monitor and keyboard size may also be an important consideration for reducing MSS in laptop computer operators.

Although respondents generally reported ‘no difficulty’ with most aspects of their role function, they experienced some difficulties in performing certain academic and leisure activities, such as typing 10 pages on their laptop computers, carrying books around campus, and sports activities. These results are similar to those reported by Hupert et al. (2004) and Jenkins et al. (2007) who reported that more than 40% of college students who had computer-related discomfort experienced functional limitations in their academic activities, and more than 15% of students reported using medical services (e.g., medical treatment or medication) to relieve their discomfort. Although there were no research studies that examined the effects of laptop-related discomfort on functional limitations in other activities (e.g., activities of daily living), discomfort associated with laptop computer use may affect students' current role function or future career function. Future research studies are required to assess the relationships between laptop-related discomfort and functional limitations in various activities.

The third aim of our study was to examine the relationship between laptop-related risk factors (i.e., duration of laptop computer use and percentage of time spent using each type of laptop workstation setup) and physical discomfort. Although duration of computer use has been recognized as a potential risk factor for musculoskeletal discomfort (Blatter & Bongers, 2002; Fredriksson et al., 2002; Jensen, Finsen, Sogaard, & Christensen, 2002; Tittiranonda, Burastero, & Rempel, 1999), this study did not find a significant relationship between duration of laptop computer use (i.e., length of years having a laptop computer, duration of daily laptop computer use, and duration of continuous laptop computer use) and average laptop-related discomfort. Considering that laptop computer workstation setups have a greater potential to cause more awkward postures than desktop computer workstation setups (Saito et al., 1997; Straker et al., 1997; Szeto & Lee, 2002; Villanueva et al., 1998), we assumed that there would be significant relationships between duration of laptop computer use and physical discomfort. The reason underlying this discrepancy may be related to the insufficient sample size and lack of control for additional individual risk factors. In most surveys that examined the associations between computer work duration and musculoskeletal discomfort, the sample sizes were quite large, at least 304 subjects and as many as 25,000 subjects (Juul-Kristensen et al., 2004; Katz et al., 2000; Nakazawa et al., 2002; Rossignol, Morse, Summers, & Pagnotto, 1987; Schlossberg et al., 2004).

Another plausible explanation for this discrepancy is that duration of laptop computer use was self-reported, and thus not objectively confirmed. Self-reported duration is based on subjective judgments, so respondents may over- or under- estimate their exact time period (Spielholz et al., 2001). In order to minimize this limitation, future studies are needed to measure the duration of laptop computer use by installing computer software that automatically calculates a total amount of time in use.

Percentage of time spent using each type of laptop workstation setup (i.e., desktop sitting, lying prone, lying supine, floor sitting, chair sitting, and lap sitting) also was not significantly related to average laptop-related discomfort. Asundi et al. (2010) examined the effect of three laptop workstation setups (i.e., desktop sitting, lap sitting, and lap sitting with a commercially available lap desk) on the level of discomfort with a 10-cm VAS. The results indicated that laptop computer operators reported that the desktop sitting workstation setup caused the least discomfort, with no difference between the lap and lap-desk sitting workstation setups. Based on this finding, we assumed that there would be a difference between type of laptop workstation setups and discomfort during laptop computer use. As described previously, this discrepancy may be caused by small sample size and lack of control for the additional individual risk factors. Another plausible explanation is that respondents rated their discomfort by recall, rather than as they actually used a laptop computer in the workstation setup.. Since respondents recalled discomfort severity in each of the six laptop workstation setups, their discomfort may be over- or under- estimated.

Limitations

This study had several limitations. The sample size was relatively small and limited primarily to women. Small sample sizes limit the generalizability of survey results and do not allow subgroup analyses among laptop-related risk factors, individual risk factors, and musculoskeletal discomfort. Other surveys that examined computer use and MSS in college students had a sample size of over 111 students (Hamilton et al., 2005; Hupert et al., 2004; Jenkins et al., 2007; Katz et al., 2000; Menendez et al., 2009; Schlossberg et al., 2004). Future survey studies should be done with large number of college students to obtain sufficient statistical power.

In addition, the respondents in our study were primarily women (83.3%). Several studies have reported that women have significantly higher prevalence of MSD/MSS, compared with men (Bernard et al., 1994; Brandt et al., 2004; Gerr et al., 2002; Katz et al., 2000). Future studies should keep a balance of the gender ratio, and examine gender difference as a potential risk factor of MSD/MSS.

3.5 CONCLUSIONS

We initially developed a valid and reliable instrument (Laptop Computer User Screening Survey [LCUSS]), used the instrument to describe the characteristics of laptop computer use in college students, and examined the relationships between laptop-related risk factors and physical discomfort. Overall, this study identified the following characteristics of college laptop computer operators:

1) The most common laptop workstation setups used by respondents were desktop sitting, followed by lying supine and chair sitting.
2) The most common locations of laptop computer use were home, followed by library, café and restaurant, and campus classroom.
3) The primary reasons for the location selection were accessibility of wireless internet and presence of electrical outlet.
4) Respondents spent an average of 4 hours per day on their laptop computers and approximately 1 ½ hours without any rest breaks.
5) More respondents spent more time with their laptop computers (78.6% per week) than desktop computers (21.4% per week).
6) Respondents reported that most frequently performed task activities were to check e-mail, followed by word processing, and CourseWeb or online courses.
7) Neck and upper back discomfort were the most frequent areas of discomfort reported by respondents while using their laptop computers.
8) Most respondents carried their laptop computers in a backpack or shoulder bag. The shoulder bag was reported to cause the greatest severity of discomfort.
9) More than 30% of respondents reported some degree of functional limitations in their academic and leisure activities (i.e., type 10 pages on the laptop, carry books around campus, and sports activities).
10) Respondents were more likely to report positive attitudes towards their laptop computers.

Although statistical relationships were not found between physical discomfort and laptop-related factors (duration of laptop computer use and type of laptop workstation setups), more respondents reported: greater discomfort associated with a long daily duration of laptop computer use; greater discomfort in the neck and upper back regions while working with laptop computers; greater discomfort in floor sitting and lying prone; and less discomfort in desktop sitting.

In summary, although we developed the LCUSS to identify factors associated with physical discomfort during laptop computer use, the results of the survey provide some general insights for designing laptop computer environments and developing recommendations to promote overall healthy laptop computer habits. First, since most students selected various locations and workstation setups based on presence of the technical supports rather than the environmental supports, school-based public places with a wireless internet service should be well furnished with desks, chairs, and electrical outlets for optimal workstation setup. Second, students should be encouraged to take frequent and short rest breaks of 5 minutes every half hour to avoid prolonged static postures. One way to promote breaks would be to install computer alarm software to notify students to take breaks while using a laptop computer. Third, students should use their laptop computers in a desktop sitting workstation setup with desks, chairs, or external devices (i.e., separate monitor, keyboard, or mouse). Fourth, since most students frequently reported neck and back discomfort while using a laptop computer, they should avoid excessive neck and back flexion, and arrange themselves in a relaxed and neutral posture. Lastly, carrying a laptop computer is an additional forceful exertion and strongly associated with shoulder discomfort. Thus students should consider the weight of the entire laptop bag and carry their laptop computers using a backpack with wide straps and sufficient padding, instead of a single strap shoulder bag. If students have to carry a laptop computer in a shoulder bag, they should shift between shoulders to balance the load of the laptop bag on shoulder muscles.

4.0 THE EFFECTS OF SIX SIMULATED LAPTOP WORKSTATION SETUPS ON BODY POSTURES, DISCOMFORT, AND TASK PRODUCTIVITY: AN EXPERIMENTAL STUDY

4.1 BACKGROUND AND SIGNIFICANCE

Laptop computers are widely used in many environments (e.g., classroom, bedroom, or airport), because of their compact portability and high technological performance (Moffet et al., 2002; Sommerich et al., 2007). While the size of laptop computers is getting smaller, the technological characteristics of laptop computers (e.g., hard drive space, memory, and power supply) have been improving and are currently at a similar level to standard desktop computers, with a lower cost than in the past. Additionally, the popularization of the Wi-Fi wireless network has fueled the burgeoning use of laptop computers by users who want to promptly collect information (e.g., news, weather, or sports), to check e-mail, and to use the internet anywhere or at anytime. These advantages of laptop computers (e.g., compact portability, powerful performance, and relative low price) may encourage computer operators to replace desktop computers with laptop computers. According to the International Data Corporation (2008), laptop computer sales overtook desktop computer sales for the first time in the history of the United States market, and they anticipate that portable computers (i.e., laptop computers) will account for more than 60% of all computer markets in 2010 (International Data Corporation, 2010). This trend of increased laptop computer use compared to desktop computer use has also been found among college students (Shin, 2010), who spent more time with their laptop computers (78.6% per week), than with desktop computers (21.4% per week).

Laptop computer use may involve more risk factors for musculoskeletal disorders (MSD) and symptoms (MSS) than use of desktop computers. Several research studies have identified and reported potential risk factors associated with MSD/MSS among desktop computer operators, such as prolonged computer use, repetitive movement of the wrist and hand, sustained and awkward body posture, and forceful and excessive keyboarding (Armstrong et al., 1994; Bergqvist et al., 1995b; Ferguson & Duncan, 1974; Gerr et al., 2002). However, laptop computer operators may be at more risk than desktop computer operators due to the inherent design of the laptop computer and a lack of environmental supports (e.g., desk, chair, or external devices). Generally, the design of laptop computers promotes awkward or constrained body postures during typing because of small monitors, flat keyboards, and the lack of a separate keyboard and monitor position adjustment. Use of the integrated monitor and keyboard causes uncomfortably crouched body postures, because laptop computer operators have to view a low and small monitor and use a flat keyboard and awkwardly placed track pad (Saito et al., 2000). Research studies which compared upper body postures between laptop and desktop computers, indicated that laptop computer operators assumed more trunk flexion, neck flexion, head-down tilt, inward rotation of shoulder, and ulnar deviation of the wrist than desktop computer operators (Saito et al., 1997; Straker et al., 1997; Szeto & Lee, 2002; Villanueva et al., 1998). However, most studies described body postures carried out at desktop sitting workstation setup, with or without an adjustable height desk or chair. They did not consider other laptop workstation setups used by laptop computer operators. To date, only two research studies have examined the effect of different laptop workstation setups on body postures. Moffet et al. (2002) measured upper body angles for two laptop workstation setups (i.e., desktop and lap sitting), and then compared the angle differences between the two laptop workstation setups and two laptop designs (i.e., with and without palm rest) to identify which environmental factors (i.e., laptop workstation setups vs. laptop designs) had a greater effect on body postures. The results showed that the subjects in lap sitting workstation setup had more head flexion, backward trunk inclination, and wrist extension, compared with those in desktop sitting workstation setup. Interestingly, the type of laptop workstation setups had a greater influence on body postures than the type of laptop designs. This finding was supported by Asundi et al. (2010) who reported that in lap sitting setup laptop computer operators showed more awkward body postures and discomfort rather than those in desktop sitting setup. The survey by Shin (2010) found that laptop computer operators work in a variety of laptop workstation setups (i.e., desktop sitting, lying prone, lying supine, floor sitting, chair sitting, and sitting with laptop on the lap), it is therefore important to determine the postural effects of these laptop workstation setups.

College students are in the preparatory stage for professional work, often in computer-related careers. The awkward computer postures that students have acquired during this period may influence their further work efficiency and health condition. According to survey of 400 American college students (Research and Markets, 2009), young students were more likely to own a laptop computer, compared to students over 30 years old. Interestingly, younger students reported significantly more arm/shoulder discomfort than older students, possibly because younger students were more likely to use only a laptop computer in a variety of laptop workstation setups (e.g., lying on the bed or slumping in a couch), while older students worked in traditional desktop sitting setup. Despite the increase of laptop computer use and discomfort in college students, only few lab-based research studies have been conducted on laptop-related risk factors in college students.

4.2 RESEARCH DESIGN AND METHODS

4.2.1 Research aims

The overall aim of this experimental study was to examine the effects of the six simulated laptop workstation setups on upper body postures, discomfort, and task productivity of college students. Although all six simulated laptop workstation setups (i.e., desktop sitting, lying prone, lying supine, floor sitting, chair sitting, and lap sitting) were recorded during data collection, we only report data related to the three most common laptop workstation setups (i.e., desktop sitting, lying supine, and chair sitting) that were identified by Shin (2010).

- Research aim 1: Examine the effects of the three most common laptop workstation setups on upper body postures
    - Research question 1.1: Is there a difference in upper body angles between the three simulated laptop workstation setups?
    - Research question 1.2: Is there a difference in typing style between the three simulated laptop workstation setups?

- Research aim 2: Examine the effects of the three most common laptop workstation setups on physical discomfort
    - Research question 2.1: Is there a difference in physical discomfort between the three simulated laptop workstation setups?

- Research aim 3: Examine the effects of the three most common laptop workstation setups on task productivity
    - Research question 3.1: Is there a difference in task productivity between the three simulated laptop workstation setups?

4.2.2 Research design

This research study used an experimental randomized repeated cross-over design to measure upper body postures, discomfort, and task productivity in the six simulated laptop workstation setups (see Figure 4-1).

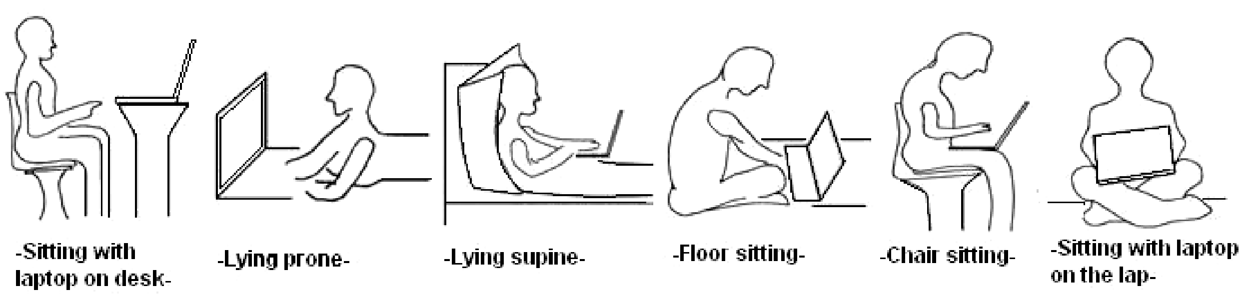


Figure 4-1. Six simulated laptop workstation setups

4.2.3 Participants

Thirty college students were recruited from the University of Pittsburgh. Subjects had to meet the following inclusion criteria: (1) undergraduate or graduate students from the University of Pittsburgh; (2) use of a laptop computer at present; (3) no co-morbidities of the upper extremity, such as neurological disorders or fractures; (4) the ability to tolerate the laboratory tasks for three hours. Exclusion criteria were: (1) presence of current musculoskeletal injuries in the back, neck, shoulder, and upper limbs.

Advertising flyers (see Appendix F) containing the purpose, procedure, benefits, and eligibility were circulated and posted throughout the college campus one month prior to the study. In addition to the recruitment using the flyers, Master of Occupational Therapy (MOT) students were invited to participate in the research study with research invitation blurb (see Appendix G). Written consent was obtained prior to participation in the study.

4.2.4 Instrumentation

4.2.4.1 Laptop computer user screening survey (LCUSS)

The self-administered LCUSS (see Appendix E) was used to identify demographic characteristics of the sample and select the most common laptop workstation setup to use during analysis. Development procedures (i.e., validation process of item content and test-retest reliability) and item rationales of the LCUSS are detailed in Chapter 3. The LCUSS is divided into the following 12 sections with total 75 questions: (1) demographic information (14 items); (2) location of laptop computer use (2 items); (3) laptop transportation methods (3 items); (4) laptop related tasks (1 item); (5) laptop specifications (5 items); (6) usage time (5 items); (7)

laptop workstation setups (3 items); (8) overall laptop related discomfort (2 items); (9) student health related role functioning (16 items); (10) attitude toward the laptop computer (9 items); (11) recreational activities (7 items); and (12) previous/current health status (8 items).

4.2.4.2 Upper body angles

<u>ImageJ software program</u>

ImageJ software, an open-access Java-based image processing and analysis software program developed at the United States National Institutes of Health (NIH), was used to digitize the snapshots and calculate the angles (Ferreira & Rasband, 2010). From the video clips of this study, each angle is estimated by selecting three anatomical landmarks with the angle tool () in the ImageJ software (see Figure 4-2). The angle is automatically displayed in the result window by clicking the “analyze button.”

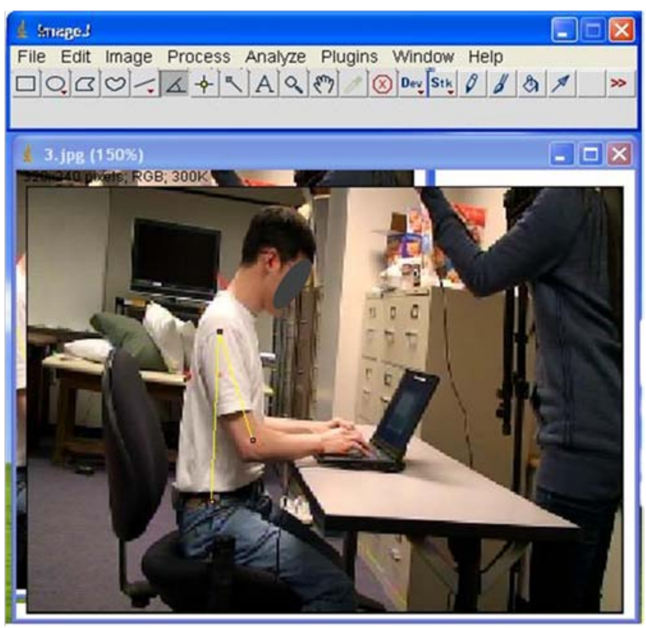


Figure 4-2. Measurement of the angles using the ImageJ software program

ImageJ software has been considered a reliable and valid method for measuring body angles. In biological and medical research, this software is widely used for image analysis (Noguchi, Kikuchi, Ishibashi, & Noda, 2003; Tchoukalova, Harteneck, Karwoski, Tarara, & Jensen, 2003). Roush, Bustillo, and Low (2008) compared quadriceps angles between the ImageJ program and direct goniometric measures. The results of the ICCs showed excellent agreement for the interrater reliability (ICCs = 0.98, 95%CI = 0.97 – 0.99, angle difference = 1.05°). The ICCs between ImageJ program and goniometric measures were .89 (95%CI = 0.83 – 0.93, angle difference = 2.06°).

In the following section, we provide definitions for each anatomical landmark used to develop the upper body angles using the ImageJ software. In addition, we describe camera and workstation setup configuration, and information regarding the validation process for video-based observation using the ImageJ software.

Postural angle estimation

Eleven anatomical landmarks were used to calculate upper body angles using the ImageJ software. Adhesive paper markers were placed bilaterally (except for marker 1), on the following anatomical points: (1) C7 spinous process, (2) superior iliac crest (center of rotation of hip), (3) inferior angle of the scapula, (4) tragus, (5) acromion process, (6) lateral epicondyle of the humerus, (7) styloid process of ulna, (8) lateral head of the 5^{th} metacarpal bone, (9) dorsal head of the 3^{rd} metacarpal bone, (10) dorsal aspect of the wrist joint in line with the base of the 3^{rd} metacarpal bone, and (11) 90 mm from the wrist marker in the middle of the dorsal surface of the forearm. Before starting each laptop workstation setup, these landmarks were checked using a prepared picture that indicated the location of landmarks, to confirm their placement accuracy (see Figure 4-3). Based on these markers, a total of 12 upper body angles were measured using the ImageJ software (see Table 4-1). To facilitate marker identity, subjects wore a short T-shirt that did not restrict arm movements or obscure the anatomical markers. The color of the T-shirts was complementary to the marker's color.

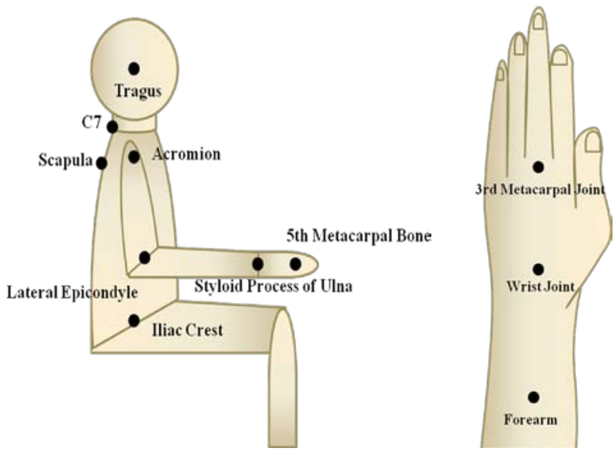


Figure 4-3. Maker position in the lateral view and hand

Table 4-1. Upper Body Angles Adopted in Observational Study

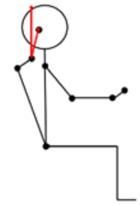
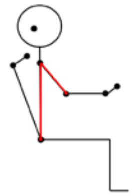
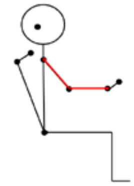
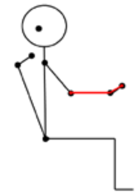
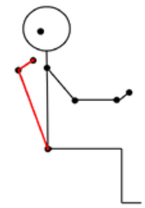
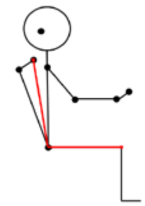
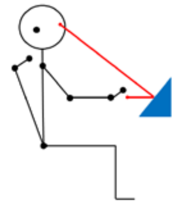
Body angle	Definition	Measurement of angle
Neck angle	Angle formed by the vertical line and the line from the C7 spinous process to tragus (Ankrum & Nemeth, 2000)	
Shoulder angle [a]	Angle formed by the line from the acromion process to the lateral epicondyle line relative to the trunk line (Villanueva et al., 1998)	
Elbow angle [a]	Angle formed by the acromion process, lateral epicondyle of the humerus, and styloid process of the ulna (Villanueva et al., 1998)	

Table 4–1 (Continued).

Body angle	Definition	Measurement of angle
Wrist angle [a]	Angle formed by the lateral head of 5th metacarpal bone, styloid process of the ulna, and lateral epicondyle of the humerus (Straker et al., 1997)	
Ulnar/radial deviation [a]	Angle formed by the dorsal head of 3rd metacarpal bone, dorsal aspect of the wrist joint in line with the base of 3rd metacarpal bone, and 90 mm from the wrist marker in the middle of the dorsal surface of the forearm (Burgess-Limerick, Shemmell, Scadden, & Plooy, 1999)	
Thoracic bend angle	Angle formed by the C7, inferior angle of the scapula, and superior iliac crest (Sommerich et al., 2002)	
Trunk angle	Angle formed by the horizontal line and the line between the C7 spinous process to superior iliac crest (Sommerich et al., 2002; Villanueva et al., 1998)	
View angle	Angle formed by the horizontal line and the line between the eye and the middle of the monitor (Berkhout et al., 2004; Jonai et al., 2002; Villanueva et al., 1998)	

Note. [a]includes the right and left angles

In addition to body angles, the following workstation setup parameters were manually measured for each laptop workstation setup:

1) LCD monitor tilt angle (Degrees)
2) Laptop depth: Distance between the edge of a desk and the edge of the computer (cm)
3) Chair height (cm)

Camera and workstation setup configuration

Three cameras (right camera: JVC GR-D72U; left camera: Sony DCR-TRV50; and overhead camera: Sony Handycam HDR-HC7) were mounted on tripods and used to record subjects' typing postures. The two cameras on the right and left sides were used to obtain lateral views during laptop computer operation. The overhead camera was used to capture ulnar and radial deviation of the wrist. The height of the cameras was adjusted to the level of the C7 spinous process of each subject for the right and left cameras (lateral view) (Berkhout et al., 2004) and to the midpoint of a line joining the radial and ulna heads for the wrist and hand camera (overhead). All cameras were adjusted with the power zoom so that all markers were detectable in the LCD panel.

In order to conduct the six simulated laptop workstation setups, the laboratory room was configured in three stations: the desk, chair, and mat stations (see Figure 4-4). A standardized desktop station was used for 'desktop sitting.' An un-adjustable desk and adjustable chair were used. The desk height was fixed at 72 cm. This station was set up to be similar to a typical classroom situation where the desk is usually not adjustable, while the chair height is adjustable. In desktop sitting, all subjects adjusted the height of chairs to place their feet on the floor and laptop computers to their preferred settings (i.e., LCD monitor tilt angle and laptop depth). The main difference between the simulated desktop and chair sitting workstation setups were the placement of laptop computers and the presence or absence of the desk. In chair sitting, all subjects placed the laptop computers on their laps.

A mat was used for the other simulated laptop workstation setups; floor sitting, lap sitting, lying supine, and lying prone. The floor and lap sitting were similar, except for placement of the laptop computers: in the former subjects placed their laptop computers on the floors, while for the latter subjects placed them on their laps. In lying supine, subjects leaned their trunks onto cushions and placed the laptop computers on their laps. The laptop computers were placed on the floor in lying prone, with subjects propped on their elbows. An overview of the laptop workstation setups and the placement of laptop computers is shown in Figure 4-4.

Desktop sitting

Chair sitting

Floor sitting

Lap sitting

Lying supine

Lying prone

Figure 4-4. Photograph of the laptop workstation setup configuration

Validation process of the ImageJ measurement

A well-defined and accurate method for assessing exposure to the risk factors that may be associated with musculoskeletal problems has been considered an important issue in the field of the ergonomics (David, 2005; Spielholz et al., 2001). Although video-based observation methods have been frequently used to obtain the postural risk factors in several studies related to musculoskeletal problems (McAtamney & Nigel Corlett, 1993; Occhipinti, 1998; Paquet, Punnett, & Buchholz, 2001), researchers must have confidence of the validity of their methods by determining the amount of errors between observational and direct estimates. Therefore we compared measurement errors when measuring the postural angles using an ImageJ and a handheld goniometer on one subject as a validation process.

One subject was asked to pose with a laptop computer in each of the six simulated laptop workstation setups. We then captured three body snapshots (i.e., right, left, and overhead) to obtain the 11 upper body angles and 1 workstation setup parameter (i.e., LCD monitor tilt angle) for each laptop workstation setup. The test procedure (i.e., postural angle estimation and camera and workstation setup configuration) was conducted under the same conditions as the main experimental study. Simultaneous with the snapshot capture, these 12 angles (i.e., 11 body angles and 1 LCD monitor tilt angle) were directly measured with a goniometer and recorded by the PI. The body images derived from video capture were then calculated for each angle by the ImageJ program, and compared to the direct goniometer measurement.

The results of angles measured by two measurement methods (i.e., ImageJ vs. goniometer) were similar (see Appendix J). The average absolute differences across 12 angles were 0.67 ± 0.48 degrees for the desktop sitting, 1.36 ± 0.77 degrees for the chair sitting, 0.84 ±

0.70 degrees for the floor sitting, 1.33 ± 0.75 degrees for the lap sitting, 1.36 ± 1.48 degrees for the lying supine, and 0.91 ± 0.53 degrees for the lying prone (see Table 4-2).

In a study by Shea et al. (1998), that compared computer-assisted measurement with manual measurement, the measurement error was 2.6 degrees (range = 2.3 – 3.3 degrees) for computer-assisted measurement and 3.3 degrees (range 2.5 – 4.5 degrees) for manual measurement. They concluded that computer-assisted measurement was accurate, consistent, and valid, and in some ways might be more powerful than manual measurement due to decreased errors resulting from inappropriate manipulation or variability of the goniometer. In our study, the variability of angle differences was less than 2 degrees between the ImageJ and handheld goniomter measurements. Therefore, we considered that this variability was reasonable angle differences and that we could be confident in the validity of the video-based observation method.

Table 4-2. Absolute Differences in Angular Measurements Between ImageJ and Goniometer

	Absolute differences (degree)		
	Mean ± SD	Minimum	Maximum
Desktop sitting	0.67 ± 0.48	0.13	1.77
Chair sitting	1.36 ± 0.77	0.24	2.52
Floor sitting	0.84 ± 0.70	0.04	1.96
Lap sitting	1.33 ± 0.75	0.06	2.46
Lying supine	1.36 ± 1.48	0.36	5.75
Lying prone	0.91 ± 0.53	0.11	1.69

4.2.4.3 Discomfort rating chart

All subjects completed a discomfort rating chart to determine the intensity of discomfort of neck, shoulder, arm, hand, wrist, and trunk, after completing each of the six simulated laptop workstation setup. The chart consisted of Corlett and Bishop's body chart (Corlett & Bishop, 1976) and a horizontal 10-cm visual analogue scale (VAS) (Bijur et al., 2001; Downie et al., 1978; Gallagher et al., 2002; Kumar et al., 1999; McCormack et al., 1988) (see Appendix K). After identifying each body area in which subjects experienced discomfort while working on a laptop computer, subjects determined the levels of discomfort severity using the VAS, which ranged from 0 cm (i.e., no discomfort) to 10 cm (i.e., unbearable discomfort). Subjects were asked to place an 'X' mark on the line at the point most closely describing their discomfort for each body region while using the laptop computer in each of the six simulated laptop workstation setups.

4.2.4.4 Keyboard personal computer style (K-PeCS)

The K-PeCS, observational checklist, was used to assess personal typing style while using a laptop computer (Baker & Redfern, 2005). This instrument consists of 19 items that are divided into three sections: (1) static posture, which includes items that are related to relatively unchanging body postures during typing (e.g., torso angle, head flexion angle, shoulder flexion angle, and elbow flexion angle); (2) dynamic posture (i.e., frequency), which consists of items that are related to flexible joint movements by the typists on the wrists, hands, and fingers (e.g., wrist/hand movement, wrist ulnar angle > 20°, wrist extension angle > 15°, changes in pronation, isolated 5th digit, isolated thumb, space bar activation, number of digits used to type, MCP extension, DIP/PIP curve, and hypermobility); and (3) tension and force, which includes items that describe key strike forces and the use of supports (e.g., back rest use, forearm support use, wrist support use, and force). In most items, both the right and left hands are assessed separately. The K-PeCS is rated either live or from a video that captures the keyboarding postures in sagittal (left and right body postures) and transverse (wrist and hand postures) planes. The duration of video data must be at least 1 minute. The K-PeCS items are rated on an ordinal scale.

Overall, the K-PeCS has demonstrated excellent inter-rater reliability (ICCs = 0.90, $p < .001$), and intra-rater reliability (ICCs = 0.92, $p < .001$) (Baker, Cook, & Redfern, 2009). Most individual items' reliability showed excellent results, except six items which fell below an ICCs of 0.75 that indicated moderate reliability: torso angle (ICCs = 0.71, $p < .001$), force (ICCs = 0.67, $p < .001$), isolated thumb (ICCs = 0.63, $p < .001$), and hypermobility (ICCs = 0.33, $p < .001$) for the inter-rater reliability and force (ICCs = 0.67, $p = .04$), isolated thumb (ICCs = 0.62, $p < .001$), ulnar deviation angle (ICCs = 0.71, $p < .001$), and PIP/DIP curve (ICCs = 0.73, $p < .001$) for the intra-rater reliability. The concurrent and content validity of the K-PeCS were also well established (Baker et al., 2009; Baker & Redfern, 2005), as well as the ability to identify the potentially problematic postures of keyboard users (Baker & Redfern, 2009).

To improve the reliability of the K-PeCS measurement in this study, we assessed the reproducibility of the K-PeCS items within raters (i.e., intra-rater reliability). ICCs were used to calculate the reliability of each item, and considered an excellent reliability greater than or equal to 0.80 and a good reliability greater than 0.5 and less than 0.8 (Hulley, 2007). In general, all ICCs were good to excellent (range = 0.57 – 0.94, $p < .05$), except for three items: wrist ulnar angle > 20˚ (ICCs = 0.38); wrist extension angle > 15˚ (ICCs = 0.34); and isolated thumb (ICCs

= 0.47). In the static posture section, excellent ICCs were demonstrated for all items, while the tension and force section ranged from good to excellent.

4.2.4.5 Task productivity

Task productivity was assessed using typing speed (words/min) and by absolute and relative number of errors. The computer software program used to present the essays and generate the scores was "Typing Master Pro™ (Typing Master Finland, Inc., Helsinki, Finland)." This program saves personal typing data by subject case number, and automatically calculates 6 productivity measurements: gross speed, net speed, accuracy, gross hits, net hits, and error hits. In order to calculate typing speed (i.e., gross and net speed) and accuracy, three variables (i.e., gross, net, and error hits) are required. Each definition used in this study is as follows;

- Gross speed indicates the total number of keystrokes divided by total time.
- Net speed is calculated by taking the number of correct words typed (i.e., total number of keystrokes – number of error hits), divided by total time.
- Accuracy is calculated by taking the number of correct words typed (i.e., total number of keystrokes – number of error hits), divided by the total number of keystrokes, and then multiplying by 100 to provide a percentage.
- Gross hits are the total number of keystrokes.
- Net hits are calculated by subtracting the error hits from the total number of keystrokes.
- Error hits are the total number of incorrect words typed.

The essays typed by the subjects were provided in the typing software program. These essays were at the fourth-grade reading level. The PI selected six essays that were long enough to allow subjects to type for 10 minutes regardless of their personal typing speed. Each essay was then randomly assigned to one of the six simulated laptop workstation setups (see Table 4-3). A software timing routine began when a word was typed, and automatically terminated after 10 minutes.

Table 4-3. Essay Types for Laptop Workstation Setups

Laptop workstation setups	Essay types
Desktop sitting	Flickerbridge
Lying prone	The Adventures of Huckleberry Finn
Lying supine	The Enchanted Typewriter
Floor sitting	The History of the Telephone
Chair sitting	Difficult People
Lap sitting	Wanted Alive! Tigers in the Wild

4.2.5 Procedures

Subjects were provided a general description of the research study (e.g., purpose, procedure, inclusion eligibility, risk factors, and benefits) by the principal investigator (PI) before signing the consent form approved by the University of Pittsburgh Institutional Review Board (IRB#PRO09030092/MOD09030092-01). Each subject randomly picked one of six sheets outlining the essay type to determine the order of the six simulated laptop workstation setups, and then filled out the LCUSS. While subjects completed the LCUSS, the PI prepared the first laptop workstation setup and camera configuration.

After completing the LCUSS, subjects performed the keyboard text-entry task in each of the six simulated laptop workstation setups. Each subject typed for 10 minutes at each simulated laptop workstation setup with a 5-minute break in between. Prior to the laptop keyboarding tasks, subjects were asked to be as natural as possible, while typing in the simulated laptop workstation setups. The subjects were, however, shown a picture of each laptop workstation setup to provide basic guide (see Figure 4-1). Subjects could change the height of the chair and monitor angle to their preferred height and angle, and these changes in the workstation setup parameters (e.g., LCD monitor tilt angle, laptop depth from the edge of a desk, chair height) were recorded by the PI at the completion of each of the tasks.

After completing each of the six simulated laptop workstation setups, all subjects were asked to immediately rate their discomfort levels on the VAS. In the meanwhile, the PI set up the next laptop workstation setup and camera configuration. The level of lighting in the laboratory room was kept constant during the experimental session across all subjects. The amount of time required to complete this experiment was approximately 2 ½ hours, including 50 minutes for the LCUSS and consent form, 60 minutes for the six simulated laptop workstation setups, and 40 minutes for the rest breaks between workstation setups.

4.2.6 Data management and processing

All subjects' identities were indicated by case number. All information about subjects obtained from this study was stored in a locked file cabinet. All data (i.e., LCUSS, upper body angles, K-PeCS, discomfort, and task productivity) were entered into Microsoft Office Excel 2007, and then transferred into a SPSS 17.0 software program for analysis.

To obtain the upper body angles, the data in the videotape was downloaded to a personal computer into video clip types using an external DVD movie burner for digital storage (HP DVD movie writer dc 4000) and later scoring of angles. Subjects' postures were analyzed using a time-sampling technique that was characterized as the systematic recording of frequency or variation of specific behaviors during the observation period (Li & Buckle, 1999). In time sampling, subjects' postures were recorded in real time using the video recording system, and divided into a number of equal time intervals (David, 2005; Suen & Ary, 1986). In this study, the video file was divided into 1-minute intervals during the 10-minute laptop keyboarding task. To prevent a rater from identifying a snapshot (i.e., electronic picture in jpg format) at a preferred starting point, a starting point was randomly selected from either 1, 2, 3, 4, or 5 seconds. After selecting the first snapshot, ten time points for each body angle were selected at 1-minute intervals. Each snapshot was analyzed by the ImageJ software to obtain a numerical value of body angles. These angles were entered into a database and averaged across the 10 data sets. Each snapshot had a time stamp (e.g., day, hour, minute, and second) that the picture was taken.

In order to rate typing style using the K-PeCS, 1-minute video clips were extracted from original video files. These video clips include two lateral views (i.e., right and left side) and one transverse view (i.e., hand and wrist side). The PI selected the last minute of typing to avoid the potential of conscious actions about being video-recorded and to observe a more stereotypical moment (Baker, Sussman, & Redfern, 2008; James, Harburn, & Kramer, 1997).

Intensity of discomfort was assessed using the 10-cm VAS. The VAS was manually scored by measuring how far along the line (in centimeter) from the 'no discomfort' anchor that the line was marked. Task productivity (e.g., typing speed and number of errors) was automatically stored in a preinstalled keyboarding program, Typing Master Pro™ (Typing Master Finland, Inc., Helsinki, Finland).

4.2.7 Data analyses

All statistical analyses were performed using the SPSS 17.0 statistical package program. Demographic characteristics of the study sample (*N* = 30) were summarized using relative frequency distributions for the nominal and ordinal data, and means and standard deviation (SD) for the continuous data. Prior to analysis, we identified the three most common workstation setups used: desktop sitting, lying supine, and chair sitting (Shin, 2010). All further data analysis for this study was delimited to these three workstation setups.

Research question 1.1: Difference in upper body angles

The average angle for each upper body area was calculated using mean and standard deviation. Data were analyzed by a repeated measures analysis of variance (ANOVA). A separate ANOVA model was used for each body angle as the dependent variables, and each of the three simulated laptop workstation setups as the independent variables. If there were significant main effects between the three simulated laptop workstation setups, Bonferroni post-hoc comparisons were conducted to determine significant differences in the outcome variables among the laptop workstation setups.

Effect size was determined by partial eta-squared ($\eta_P{}^2$). In a repeated measures ANOVA model, the partial eta-squared is commonly used in conjunction with statistical significance, and it is interpreted as "the proportion of variance that a variable explains that is not explained by other variables" (Field, 2009, p. 791). In a repeated measures ANOVA model with only a single factor, effect size scores for partial eta-squared and eta-squared are identical. Interpretation for strength of these values was: small ($\eta_p^2 = .01$), medium ($\eta_p^2 = .06$), and large ($\eta_p^2 = .14$) (Cohen, 1998).

Research question 1.2: Difference in typing style

We completed descriptive statistics for the K-PeCS to identify frequency and percentage distribution of each item. We compared the K-PeCS items among the three simulated laptop workstation setups using a Friedman's ANOVA and the Wilcoxon signed rank test for post-hoc comparisons (asymptotic significance, 2-tailed). Statistical significance was set at $p < .05$.

Research question 2.1 and 3.1: Difference in physical discomfort and task productivity

Repeated measures ANOVAs were used to analyze differences in physical discomfort and task productivity (i.e., gross speed, net speed, accuracy, gross hits, net hits, and error hits) among the three simulated laptop workstation setups. If the main effect was significant between the laptop workstation setups, Bonferroni post-hoc comparisons were conducted. In addition to statistical significance, we reported the partial eta-squared, a measure of effect size. The selected critical level of alpha significance for all tests was $p < .05$.

4.3 RESULTS

4.3.1 Participants

Table 4-4 presents the demographic characteristics of 30 subjects, 25 females and 5 males, who were enrolled in this study. All subjects were full-time students from the University of Pittsburgh.

Most subjects were graduate students (56.7%), followed by junior (20%) and senior (20%), and sophomore (3.3%). The ages of students ranged from 20 years to 48 years, with mean age of 25.97 ± 7.29. The majority of subjects were also non-Hispanic or Latino (100%), white (63.3%), right-handed (90%), and never married (86.7%).

Table 4-4. Participants' Demographic Characteristics

Demographics	Mean ± SD or number (%)
Age, years	26.0 ± 7.3
Male	28.4 ± 5.2
Female	25.5 ± 7.6
Gender	
Female	25 (83.3%)
Ethnicity	
Non Hispanic or Latino	30 (100.0%)
Race	
Asian	10 (33.3%)
Black or African American	1 (3.3%)
White or Caucasian	19 (63.3%)
Dominant hand	
Right	27 (90.0%)
Left	2 (6.7%)
Both	1 (3.3%)
Current enrollment status	
Full time student	30 (100.0%)
Class level	
Sophomore	1 (3.3%)
Junior	6 (20.0%)
Senior	6 (20.0%)
Graduate students	17 (56.7%)

4.3.2 Research question 1.1: Difference in upper body angles

Table 4-5 provides the results of mean, standard deviation (SD), and ANOVA for each body angle for the three simulated laptop workstation setups.

Table 4-5. Comparison of Angles and ANOVA Summary between Three Laptop Workstation Setups

Posture angles	Mean ± SD (degree)			F	p^c	η_P^2
	Desktop sitting	Lying supine	Chair sitting			
Neck angle	46.0 ± 6.7	35.2 ± 8.1	55.5 ± 6.7	104.25	< **.001**	.78
Rt. shoulder angle$^{\alpha}$	21.9 ± 7.8	-3.8 ± 7.6	0.2 ± 8.7	167.40	< **.001**	.85
Lt. shoulder angle$^{\alpha}$	23.0 ± 7.7	-4.0 ± 7.6	1.1 ± 9.0	188.46	< **.001**	.87
Rt. elbow angle[a]	109.1 ± 8.8	111.2 ± 14.8	112.4 ± 12.9	0.93	.40	.03
Lt. elbow angle[a]	111.6 ± 9.1	112.2 ± 15.0	114.2 ± 13.3	0.60	.55	.02
Rt. wrist angle[a]	-0.5 ± 7.2	4.5 ± 11.6	-3.4 ± 10.2	13.30	< **.001**	.31
Lt. wrist angle[a]	-2.5 ± 7.6	5.4 ± 12.5	-6.5 ± 12.7	28.31	< **.001**	.49
Rt. ulnar/radial deviation[b]	5.5 ± 2.3	10.5 ± 4.4	12.5 ± 4.4	72.40	< **.001**	.71
Lt. ulnar/radial deviation[b]	7.5 ± 2.3	12.2 ± 3.5	13.7 ± 4.7	71.58	< **.001**	.71
Thoracic bend angle$^{\alpha}$	133.4 ± 9.1	115.6 ± 6.8	124.5 ± 8.1	134.88	< **.001**	.82
Trunk angle$^{\alpha}$	94.2 ± 5.0	128.0 ± 11.3	103.7 ± 6.1	173.93	< **.001**	.86
View angle	32.6 ± 3.7	25.8 ± 11.6	50.4 ± 5.0	87.80	< **.001**	.75

Note. Rt. = Right; Lt. = Left; [a]The plus sign (+) indicates flexion and the minus sign (–) indicates extension; [b]The plus sign (+) indicates ulnar deviation of the wrist and the minus sign (–) indicates radial deviation of the wrist; [c]Statistical significance was set at $p < .05$

In general, most angles were significantly different between the three simulated laptop workstation setups, with a large effect size of more than 0.14. Only elbow angles showed no significant difference and a small effect size. As significant main effects were found, Bonferroni post-hoc analyses were calculated. Most angles were significantly different among all three simulated laptop workstation setups, except for right wrist angle between desktop and chair sitting (p = .17), left wrist angle between desktop and chair sitting (p = .07), and left ulnar/radial deviation between lying supine and chair sitting (p = .05) (see Appendix L).

4.3.3 Research question 1.2: Difference in typing style

Friedman's ANOVA results indicated a significant main effect for 15 of the 19 K-PeCS items among the three laptop workstation setups (see Table 4-6 and Appendix M). Post-hoc analyses using the Wilcoxon signed rank tests revealed that of the 45 post-hoc models, 28 were significant ($p < .05$) (see Appendix N).

Table 4-6: Significant Main Effect for 15 Items

K-PeCS items	Mean rank			χ^2	*df*	*p*
	Desktop sitting	Lying supine	Chair sitting			
Torso angle	2.7	1.3	2.1	42.20	2	< **.001**
Back rest use	2.5	1.5	2.0	28.53	2	< **.001**
Head flexion angle	1.3	2.5	2.3	41.61	2	< **.001**
Rt. shoulder flexion angle	2.7	1.6	1.7	42.09	2	< **.001**
Lt. shoulder flexion angle	2.7	1.6	1.6	44.00	2	< **.001**
Forearm support use	1.7	2.1	2.3	10.66	2	< **.001**
Rt. wrist support use	2.1	1.8	2.1	6.23	2	**.04**
Rt. ulnar angle > 20°	1.6	2.2	2.3	17.03	2	< **.001**
Lt. ulnar angle > 20°	1.5	2.3	2.2	19.97	2	< **.001**
Rt. wrist extension > 15°	1.7	1.7	2.6	18.27	2	< **.001**
Lt. wrist extension > 15°	1.9	1.8	2.4	8.91	2	**.01**
Rt. isolated 5th digit	1.9	2.3	1.9	10.67	2	< **.001**
L-3 MCP hyperextension	1.9	2.2	1.9	10.75	2	< **.001**
L-4 MCP hyperextension	1.6	2.2	2.2	11.56	2	< **.001**
L-5 MCP hyperextension	1.5	2.3	2.2	22.46	2	< **.001**

Note. Rt. = Right; Lt. = Left; MCP = Metacarpophalangeal joints

4.3.4 Research question 2.1: Difference in physical discomfort

Figure 4-5 displays the average discomfort experienced by participants during laptop computer use for each of the three simulated laptop workstation setups. While desktop sitting and lying supine showed a similar trend for discomfort, the discomfort in chair sitting was greater than the discomfort reported in the other two laptop workstation setups. For upper back discomfort, the main effect was significantly different among the three laptop workstation setups (F (2, 58) = 6.01, $p < .001$, $\eta_P^2 = .17$), and post-hoc analyses were also significantly different between desktop sitting vs. chair sitting (p = .01) and lying supine vs. chair sitting (p = .02). Although there were significant main effects for the right (F (2, 58) = 3.76, p = .03, $\eta_P^2 = .12$) and left shoulder (F (2, 58) = 3.32, p = .04, $\eta_P^2 = .10$) among the three laptop workstation setups, post-hoc analyses showed no significant differences (see Appendix O and P). While the shoulder and upper back showed medium to large effect sizes (η_P^2) among the three laptop workstation setups, the other body areas showed smaller effect sizes. Although there were no significant differences for neck discomfort among the three laptop workstation setups, respondents rated the neck area as having the greatest area of discomfort compared to other body areas.

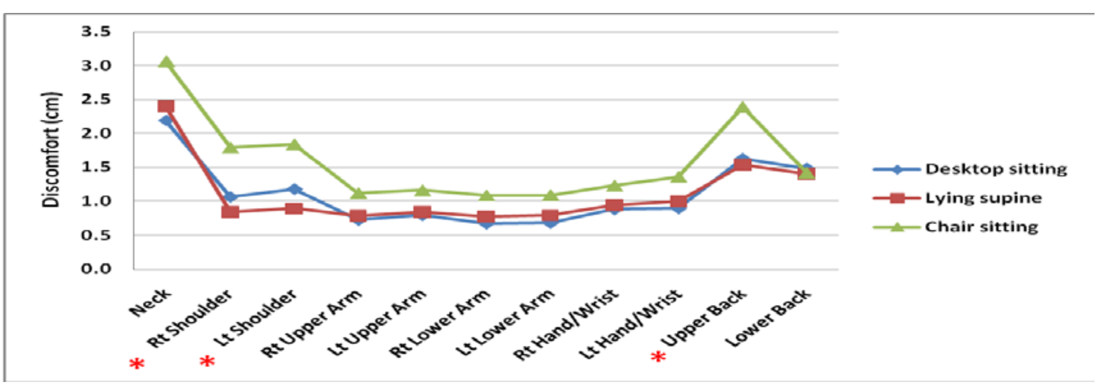


Figure 4-5. Overall discomfort reported following use of the three laptop workstation setups

Note. Rt. = Right; Lt. = Left; *Asterisk indicates significant difference among the three simulated laptop workstation setups

4.3.5 Research question 3.1: Difference in task productivity

Both the main effects for speed (i.e., gross and net speeds) and typing hits (i.e., gross and net hits) were statistically significant (all p < .001) with a large effect size (all η_P^2 > .59), while accuracy (p = .37, η_P^2 = .03) and error hits (p = .73, η_P^2 = .01) did not show significant differences among the three laptop workstation setups (see Appendix Q). Most results derived from post-hoc analyses were significant (p < .05), except for net speed and net hits between desktop sitting and lying supine (p = .10) (see Appendix R). Overall, faster typing speed and more typing hits were observed during desktop sitting, followed by lying supine and then chair sitting.

4.4 DISCUSSION

With the advantage of portability fulfilling everyday computing needs, laptop computers are frequently used in a variety of workstation setups without appropriate equipment (e.g., desk, chair, or external device). Therefore, in reality, it can be difficult to apply postural implications of traditional computer workstation setups to laptop computer operators. To date, only two experimental studies have compared several laptop workstation setups (i.e., desktop sitting, lap sitting, or lap desk sitting) on upper body postures and musculoskeletal discomfort (Asundi et al., 2010; Moffet et al., 2002). However, research studies are still lacking that provide appropriate information on how various laptop workstation setups affect laptop computer operators, in terms of body postures and discomfort. This experimental study provides preliminary data in this area as it describes upper body angles, typing style, physical discomfort, and task productivity in the three most common laptop workstation setups reported by a sample of college students (i.e., desktop sitting, chair sitting, and lying supine). In this discussion, we provide a summary of results in light of previous research, problems or limitations, and suggestions for future research.

The first aim for this study was to examine the effects of the three most common laptop workstation setups on body postures. Overall, type of laptop workstation setups had a significant influence on upper body angles. Specifically, in chair sitting, subjects assumed more awkward body postures than those in desktop sitting: increased trunk extension, thoracic flexion, neck flexion, wrist extension, ulnar deviation, and view angle. Our results are consistent with the findings of Moffet et al. (2002) who reported that in chair sitting, laptop computer operators assumed increased trunk extension, neck flexion, and wrist extension, compared with those in desktop sitting. Asundi et al. (2010) also found that laptop computer operators' neck flexion and wrist extension were increased in chair sitting. However in both previous research studies, no significant difference was observed for ulnar deviation of the wrist between the two laptop workstation setups (i.e., desktop vs. chair sitting), while our findings showed that subjects increased ulnar deviation of the wrist during chair sitting. These differences may be due to the adjustable chair used in the current study. In previous research studies, subjects could not adjust the height of their chair, while our sample changed the chair height by preference. This experimental condition may allow our sample to adjust their laptop workstation setups to assume more neutral wrist postures, compared with previous research studies.

In lying supine, subjects assumed more neutral body postures as compared to those in chair sitting: less neck flexion, wrist extension, ulnar deviation, thoracic flexion, and view angle. It was particularly interesting to note that neck flexion decreased more than 20° when lying supine compared to chair sitting. Pheasant and Haslegrave (2006) indicated that a difference of

6° in neck flexion caused a torque change of 9% around the C7, suggesting that small changes of neck flexion may have a great influence on muscle load of the neck that may be associated with neck discomfort. In our study, subjects showed the least neck flexion during lying supine, possibly because subjects could assume more comfortable upper body postures by supporting their trunk against the back cushion. Some subjects also supported their necks against the wall. In this posture, subjects may decrease the likelihood of neck discomfort, as the center of gravity of the head lies over the entire vertebral column (Greene & Roberts, 2005).

Interestingly, we observed several compensatory body postures that may be associated with physical discomfort during typing tasks, even though we did not measure the frequency of these postures. We believe that most subjects assumed compensatory postures to reduce their physical discomfort, possibly caused by the low heights of keyboards and monitors. For example, in lying supine, we noticed that the knee positions assumed by subjects affected the neck, elbow, wrist, and view angles. When subjects raised their knees and positioned laptop monitors at eye level, subjects tended to *assume a* more neutral body posture with lesser neck flexion and view angles, and more neutral wrist angles than subjects who kept their legs straight. Although we did not measure the relationships between compensatory postures and upper body angles or discomfort, future research studies should examine these relationships. Currently, there is no published evidence that explores postural angles in lying supine with desktop and chair sitting. Therefore these findings may expand the understanding of workstation setups used by laptop computer operators.

Another interesting observation was a floating wrist position of subjects while using a laptop computer. We noticed that when subjects kept their wrists floating above the keyboard during typing, the shoulder abduction and ulnar deviation tended to be increased, while the wrists tended to be maintained in a neutral posture. The postural effects of a floating wrist position have been a controversial issue among researchers. Some researchers have reported that this posture reduces wrist flexion and extension and ulnar deviation, resulting in more neutral wrist postures (Aaras, Horgen, Bjorset, Ro, & Walsoe, 2001; Albin, 1997; Cook & Burgess-Limerick, 2002), while others have reported increased MSD/MSS while floating the wrists above the keyboard (Bendix & Jessen, 1986; Horie, Hargens, & Rempel, 1993; Visser, de Korte, van der Kraan, & Kuijer, 2000). Assessment of this compensatory movement is important in order to avoid misinterpretation of the effects of the laptop workstation setups. Future studies should control these movements to establish clear relationships between upper body angles and laptop workstation setups.

In addition, distance between keyboard and abdomen appeared to affect the neck, shoulder, and elbow angles. When the laptop computers were placed closer to the abdomen (specifically in chair sitting), subjects tended to assume greater neck flexion, shoulder abduction, and elbow flexion. Previous research studies have reported that placement of the keyboard low and away from the body results in less neck and shoulder discomfort than placement of the keyboard at above elbow height and close to the body (Bergqvist et al., 1995a; Marcus et al., 2002). In chair sitting, laptop computers were placed low and close to the body (on their laps), so we believe that this placement of laptop computers may negatively affect subjects' neck and elbow flexion.

As with measurements taken using the ImageJ, the K-PeCs results also indicated large differences in typing style for static postures among the three simulated laptop workstation setups for torso, neck, and shoulder angles. Specifically, in desktop sitting, more subjects assumed neutral postures for torso and neck angles, than those in lying supine and chair sitting.

Holding sustained awkward static postures may put larger loads on the muscles and tendons, resulting in increased discomfort, compared with dynamic postures (Chaffin, 1973; Mamaghani, Shimomura, Iwanaga, & Katsuura, 2003). In lying supine, subjects showed greater torso extension angles than those in the other two workstation setups, but all subjects leaned their trunks against the back cushions to support their body weights. These back cushions may allow the subjects to assume more stable wrist and hand postures (dynamic postures) by providing stable trunk position, compared to those in chair sitting. In contrast, for chair sitting a greater number of subjects did not lean their trunk against the chair backs which, in turn, allowed greater postural variability in the trunk. This unstable trunk position may allow laptop computer operators to assume unstable wrist and hand postures: subjects frequently exceeded 20 degrees of ulnar deviation and 15 degrees of wrist extension in chair sitting. Although there are no research studies that examine the relationships between variability of the trunk and wrist and hand postures during typing, this information may inspire future studies.

Interestingly, in lying supine, neck flexion angle reported by video-based observation was considerably lower than the angle measured by the K-PeCS. This difference may be caused by the difference of postural angle estimation. In the K-PeCS, neck angle was formed by the vertical line and the line from the glenohumeral joint to the center of the ear (Baker, 2008), whereas video-based observational study used the C7 spinous process as the axis of rotation (Ankrum & Nemeth, 2000). The glenohumeral joint is located more anterior and inferior than the C7 spinouse process and close to the ear, so neck flexion angle was smaller when using the K-PeCS than when using the video-based observation method.

With regard to dynamic postures, subjects generally showed more neutral body postures in desktop sitting (i.e., wrist extension, ulnar deviation, isolated 5th digit, and left MCP hyperextension) than in the other two laptop workstation setups. This result supports the importance of a workstation environment with desks and chairs. In desktop sitting, over 50% of subjects supported their forearms (but not wrists) on the desk surface, while over 75% of subjects supported their forearms in the other laptop workstation setups, so using a forearm support may decrease postural variability of wrist and hand movements by providing stability for upper limbs. This hypothesis was supported when we compared standard deviations among the three simulated laptop workstation setups, in desktop sitting, an average of standard deviations was approximately 7.4 degrees for wrist extension and 2.3 degrees for ulnar deviation, while in chair sitting and lying supine, an average of standard deviations was approximately 12.0 degrees for wrist extension and 4.3 degrees for ulnar deviation. Delisle, Lariviere, Plamondon, and Imbeau (2006) found less variability of wrist extension and deviation when forearms on the desk surface were supported, than the chair arm rest with a smaller surface. Epidemiological research studies support the importance of supported forearms while typing: Karlqvist (1998) and Rempel (2006) reported that providing a large forearm support was an effective intervention to prevent upper body MSD/MSS in computer operators. Thus future research studies should be done to establish the relationships between forearm supports and postural variability of hand and wrist and associated discomfort.

The second aim of our study was to examine the effects of the three most common laptop workstation setups on physical discomfort. Overall, among the three laptop workstation setups, subjects showed significant differences only for their upper back discomfort. Although we did not find a significant difference for neck discomfort, this finding was similar to our previous self-report data (Chapter 3) in which respondents reported greater discomfort in their neck and upper back areas. In chair sitting, subjects experienced greater neck discomfort than the other laptop workstation setups. When considering the upper body angles in chair sitting, subjects showed increased neck flexion and view angle, possibly due to the lower monitor placement below elbow height. Low monitor placement has been considered previously as a potential risk factor for neck discomfort (Dewall, Vanriel, Aghina, Burdorf, & Snijders, 1992; Hunting et al., 1981; Psihogios, Sommerich, Mirka, & Moon, 2001; Sommerich, Joines, & Psihogios, 2001), while high monitor placement has been linked to visual stress (Bergqvist & Knave, 1994; Sotoyama, Jonai, Saito, & Villanueva, 1996). Our postural findings in chair sitting are consistent with previous evidence that low monitor placement increased neck flexion (Burgess-Limerick et al., 1998; Villanueva et al., 1996). Increased neck flexion may also be associated with greater gravitational moment, because the center of mass movements is away from the corresponding rotation center (Straker et al., 2008). These increased gravitational loads and muscle activities may result in localized muscle fatigue of the neck during chair sitting.

However, our study did not show significant differences for shoulder and neck discomfort while previous research studies reported the highest discomfort for the neck and shoulder in laptop computer operators (Harris & Straker, 2000; Sommerich et al., 2007; Straker et al., 1997). This is likely attributable to the confusion of precise body areas of neck and shoulder. Trapezius muscles connect the entire upper back, neck, and shoulder areas (Oatis, 2009), so if subjects experienced the discomfort on upper portion of trapezius, they may be confused about precise areas among upper back, neck, and shoulder. In future research studies, subjects should be well instructed to figure out precise body areas that they experience the discomfort while using a laptop computer. Another plausible explanation is the short period of rest breaks (i.e., 5 minutes) between the laptop workstation setups, or that 10 minutes of typing was not enough to elicit discomfort. This short break also has resulted in an overlapping effect of discomfort between the laptop workstation setups and body areas. Future studies should be done with a greater period of rest breaks and typing to better differentiate discomfort associated with specific workstation setups.

Another interesting finding was that discomfort in lying supine showed a similar trend to desktop sitting, possibly suggesting that providing back (i.e., cushion) or neck supports may relieve the upper body discomfort. In lying supine, all subjects leaned their trunks against a back cushion. This finding suggests that environmental supports may allow laptop computer operators to position their bodies in natural typing postures that may be associated with less discomfort.

The third aim of our study was to examine the effects of the three most common laptop workstation setups on task productivity. Overall, subjects had the fastest typing rates in desktop sitting, followed by lying supine, and then chair sitting. This result is consistent with the findings of Moffet et al. (2002) who reported that in desktop sitting, subjects wrote more characters than in chair sitting. Although we did not analyze an association between productivity and discomfort, typing speed may be linked with a comfortable computer workstation setup. Several researchers have suggested that decreased typing productivity has been directly associated with increased discomfort during computer use (Liao & Drury, 2000; Pan, Shell, & Schleifer, 1994), because discomfort derived from awkward postures may undermine precise hand and finger movements (Chaffin, Andersson, & Martin, 2006; Pan & Schleifer, 1996). However, there were no significant differences on the accuracy and error rate among the three simulated laptop workstation setups, suggesting that typing accuracy may be influenced by individual typing proficiency.

Limitations

The current study had several limitations. Its repeated exposure to the keyboarding tasks may have affected physical discomfort, so that subjects may have rated their discomfort for laptop workstation setups later in the sequence as causing more severe discomfort than the laptop workstation setups experienced earlier regardless of the actual effects. This repeated exposure may mask an actual association between the laptop workstation setup and discomfort, or falsely describe an apparent association even though there is no real association between variables (i.e., Type I error). In order to minimize this bias, each subject was randomly assigned to the order in which they used each laptop workstation setup.

In addition, the exposure time that subjects had to type in each laptop workstation setup was relatively short. Ten minutes of typing time may not be enough to demonstrate accurate physical discomfort and task productivity. If we had provided a longer time for each typing session, subject may have adjusted their postures to relieve the discomfort of each body area, and their typing speed may have improved by adapting to the typing software program, or they may have experienced greater discomfort and fatigue with reduced productivity.

In this study, we used a video-based observational method to measure each body angle. Although we compared measurement errors between the video-based observational method (i.e., ImageJ) and a handheld goniometer method as a validation process, these angles may be less accurate than those by a direct measurement method, such as a three dimensional system or electromyography. Furthermore, in time sampling, 1-minute intervals may not have been sufficient to determine accurate angles of hands and wrists that had greater postural variability. Future studies are recommended to compare postural factors using more accurate measurement methods on more dependent variables (e.g., muscle activity, joint angular velocity/acceleration, or displacement), or using a shorter time-interval for the time sampling technique (e.g., 10-second intervals). In addition, we did not analyze knee flexion and shoulder abduction which was frequently observed as a compensatory movement. In future studies, compensatory movements should be examined concurrently to provide a more complete picture of postural patterns between several laptop workstation setups.

Another important note is that although the simulated laptop workstation setups were standardized across all subjects with a picture that recommended specific postures for each workstation setup, individual typing style and postures (e.g., keyboard and monitor heights, angle of monitor, or position of lower limbs) were not controlled to replicate real-world conditions. For example, in the lying supine workstation setup, subjects adjusted the height of their monitors by raising the knee position (i.e., knee flexion) to place their monitors at eye level. There may be additional factors that may affect upper body angles and discomfort. Future studies should control these individual variations among the laptop workstation setups.

Finally, there is a possibility that the subjects experienced an overlap of symptoms due to their short rest intervals (i.e., 5-minutes rest breaks) between the different laptop workstation setups. We could address this by performing our testing over a longer period of time. We could increase both the typing time during each session and also the post-session recovery time. In that way, we could avoid a potential cumulative effect of the laptop workstation setups on the subjects' level of discomfort. Statistically, we could utilize the "Latin Square" design to control for potential order effects of laptop workstation setups. Future studies should use a larger sample size in order to strengthen statistical power. We could also improve the accuracy of our measurement methods by utilizing additional measurement tools, such as a three dimensional system or electromyography in addition to our current observational methods.

4.5 CONCLUSIONS

The current experimental study examined the effect of the three most common laptop workstation setups (i.e., desktop sitting, chair sitting, and lying supine) on upper body postures, physical discomfort, and task productivity. Overall, the use of laptop computers in the desktop sitting workstation setup maintained more neutral body postures, resulted in less discomfort and contributed to faster typing rates. These findings are consistent with previous research studies which have reported that laptop computer use in a desktop sitting workstation setup improved upper body postures, discomfort relief, and typing speed (Asundi et al., 2010; Moffet et al., 2002). Interestingly, compared with the chair sitting workstation setup, the lying supine workstation setup was associated with less flexed neck, shoulder, and view angles, less ulnar deviation, less discomfort, and faster typing speeds. We believe that these advantages of the lying supine workstation setup may result from the use of a back cushion to support the trunk and neck. Providing external supports may increase trunk and neck stability, and allow laptop computer operators to assume stable upper body postures. Considering greater neck flexion increased localized muscle strain around neck that may be associated with neck discomfort (Marcus et al., 2002; Sauter et al., 1991; Straker et al., 2008), decreased neck flexion in lying supine may lead to less neck discomfort. In addition, although more subjects showed greater shoulder flexion in desktop sitting than the other workstation setups, subjects experienced the least discomfort in their shoulders, possibly due to the forearm support on the desk surface. These findings suggest that although proper sitting postures (i.e., upright neck posture, shoulder flexion of less than 25°, elbow flexion of 90°, neutral wrist posture) are important to prevent potential musculoskeletal discomfort during laptop computer use (BSR-HFES 100, 2002), it is also important to use environmental supports to provide stable body postures.

In future studies, it is recommended that researchers provide a longer typing time than 10 minutes, in order to ensure the relationships between laptop workstation setup and physical discomfort. Additionally, future studies should evaluate compensatory movements (i.e., shoulder abduction, knee flexion, and floating wrist position) and use more accurate measurement methods (e.g., three dimensional system or electromyography) to provide a more complete picture of the physical discomfort associated with postural patterns among several laptop workstation setups.

5.0 CONCLUSIONS

The purpose of this study was to explore laptop-related risk factors associated with potential musculoskeletal symptoms (MSS) in college students. The general aims of this study were to:

- Develop a valid and reliable survey instrument (Laptop Computer User Screening Survey [LCUSS])
- Describe characteristics of laptop computer use in college students
- Examine the relationship between laptop-related risk factors and physical discomfort
- Examine the effects of the three simulated laptop workstation setups on upper body postures, physical discomfort, and task productivity

The first study identified that the LCUSS was a valid and reliable survey instrument to identify the characteristics of laptop computer use in college students. Using this instrument, we described characteristics of laptop computer use, and examined the relationship between laptop-related risk factors (i.e., duration of laptop computer use and type of laptop workstation setups) and physical discomfort in upper body. The survey revealed that this study sample used their laptop computers to do academic-based assignments (i.e., word processing task) in the home, library, or café and restaurant. The primary reasons for selecting the location of laptop computer use were accessibility of wireless internet and presence of an electrical outlet. The most common laptop workstation setups selected by this sample were desktop sitting, followed by lying supine, and chair sitting. One-third of respondents reported some degree of functional limitations in college-based activities: type 10 pages on the laptop computers, carry books around campus, and sports activities. Most of the sample showed positive attitudes towards their laptop computers and passive engagement in recreational activities. Although there were no significant relationships between the laptop-related risk factors (duration of laptop computer use and percentage of time spent using each type of laptop workstation setups) and average laptop-related discomfort, the study sample reported greater discomfort associated with: prolonged daily use of the laptop computers; neck and upper back areas while using a laptop computer; floor sitting and lying prone laptop workstation setups; and carrying the laptop computers in shoulder bag or briefcases.

The second study compared the three most common laptop workstation setups (i.e., desktop sitting, lying supine, and chair sitting) on upper body postures, discomfort, and task productivity. Overall, less discomfort and faster typing rates were achieved during desktop sitting, followed by lying supine, and chair sitting. Most upper body angles were significantly different among the three simulated laptop workstation setups:

- Desktop sitting: neutral wrist posture and ulnar deviation, upright trunk, and greater shoulder flexion than for the other workstation setups
- Lying supine: least neck flexion and greater wrist flexion and trunk extension than for the other workstation setups
- Chair sitting: greater neck flexion, wrist extension, and ulnar deviation than for the other workstation setups

This research study provides preliminary data that describes the characteristics of laptop computer use and the effects of the three most common laptop workstation setups on upper body postures, discomfort, and task productivity in college students. As described above, laptop computer operators used their laptop computers in many workstation setups, and these workstation setups affected upper body postures, discomfort, and task productivity differently. Although we identified that subjects working in desktop sitting showed fewer awkward postures, less discomfort, and faster typing speed, interestingly subjects lying supine showed similar positive patterns, but to lesser degree. These results suggest that environmental supports (e.g., desks, chairs, and back or neck supports) may have a strong positive influence on potential MSD/MSS associated with using a laptop computer in portable computing environment. Therefore, it is important to use the surrounding environments (e.g., bag, book, or cushion) to raise the height of keyboards and monitors to prevent neck and trunk flexion. If laptop computer operators cannot find any environmental supports, they should take short and frequent breaks which may relieve musculoskeletal discomfort caused by prolonged laptop computer use. In addition, laptop computer operators should carry their laptop computers using a backpack instead of a single strap shoulder bag, because survey results revealed high levels of discomfort associated with a shoulder bag.

APPENDIX A

LCUSS EXPERT PANEL EVALUATION FORM

Guideline for the Work of the Expert Panel

Purpose of the Study:

The purpose of this study is to develop and validate a reliable survey instrument (i.e., Laptop Computer User Screening Survey; LCUSS) which will be used to describe characteristics of laptop computer usage among college students.

Task of the Panel of Experts:

- To help determine the most effective survey items
- To detect specific wording or layout problems in the survey

Committee of the Experts:

- Nancy A. Baker, ScD, OTR/L, Professor, University of Pittsburgh, Department of Occupational Therapy
- Margo B. Holm, PhD, OTR/L, FAOTA, ABDA, Professor, University of Pittsburgh, Department of Occupational Therapy
- Ketki D. Raina, PhD, OTR/L, Professor, University Pittsburgh, Department of Occupational Therapy
- Rakié Cham, PhD, Professor, University of Pittsburgh, Department of Bioengineering
- Young-Joo Kim, MS, University of Pittsburgh, Department of Occupational Therapy
- Krissy Moehling, MPH, CHES, University of Pittsburgh, Department of Occupational Therapy

Content of the Survey:

The purpose of the LCUSS is to describe the characteristics of laptop computer use that may be associated with potential musculoskeletal problems among college students. Survey items have been developed from the literature content and empirical studies. The following are the sections addressed in the LCUSS:

- Demographic information
- Location of laptop computer use
- Laptop transportation methods
- Laptop related tasks
- Laptop specifications
- Usage time
- Laptop workstation setup
- Overall laptop related discomfort
- Previous/current health status
- Recreational activities
- Health related functional role
- Attitude toward the laptop computer

Directions for the Panel of Experts:

After reading the LCUSS items, please use your knowledge and expertise to help identify and refine problems with question content (i.e., overall meaning of questions and individual terms or concepts) and survey design.

- First, evaluate the quality of survey items and general survey design, according to the criteria presented on the **LCUSS Expert Panel Evaluation Form** (attached).
- Second, please suggest revisions to each item that needs to be articulated more clearly in the space provided.
- Finally, record any additional recommendations that will improve the quality of the survey.

Thank you for sharing your expertise and opinion in the validation process of the survey instrument development. The results from this validation process will be used to modify, revise, and finalize the items and designs of the LCUSS.

Hyekyoung Shin

(412) 337 - 4856

hys6@pitt.edu

LCUSS Expert Panel Evaluation Form

Date:________________________________

Name of Expert:___________________________

The targeted respondent for the LCUSS will be college students. Please circle "Yes" or "No" for each of the questions below. If answer is no, please provide which items need to modify and then suggest revisions to these items.

<u>Review of the Survey Items</u>

Section 1: Demographic Information	**YES**	**NO**
The questions are clear and understandable. (i.e., Do you have to read the item more than one to understand what it is asking?)		
Items needed to be modified and suggested revisions:		
The example is clear and appropriate.		
Items needed to be modified and suggested revisions:		
The scale is appropriate. (i.e., Do you feel the scale provided you with an appropriate way to respond?)		
Items needed to be modified and suggested revisions:		
The order of questions is clear. (i.e., Do you get confused as to which question to go to next?)		
Items needed to be modified and suggested revisions:		
Additional questions are needed in the Section 1.		
Items needed to be added in the Section 1:		

Section 2: Location of Laptop Computer Use		
2.1. Where do you use your laptop computer?	**YES**	**NO**
The question is clear and understandable. (i.e., Do you have to read the item more than one to understand what it is asking?)		
Suggested revisions:		
The example is clear and appropriate.		
Suggested revisions:		
The scale is appropriate. (i.e., Do you feel the scale provided you with an appropriate way to respond?)		
Suggested revisions:		
2.2. What is the reason for selection of location to use your laptop computer?	**YES**	**NO**
The question is clear and understandable. (i.e., Do you have to read the item more than one to understand what it is asking?)		
Suggested revisions:		
The example is clear and appropriate.		
Suggested revisions:		
The scale is appropriate. (i.e., Do you feel the scale provided you with an appropriate way to respond?)		
Suggested revisions:		

The order of questions (item 2.1 and 2.2) is clear. (i.e., Do you get confused as to which question to go to next?)		
Suggested revisions:		
Additional questions are needed in the Section 2.		
Items needed to be added in the Section 2:		
Section 3: Laptop Transportation Methods		
3.1. How do you carry your laptop computer?	**YES**	**NO**
The question is clear and understandable. (i.e., Do you have to read the item more than one to understand what it is asking?)		
Suggested revisions:		
The example is clear and appropriate.		
Suggested revisions:		
The scale is appropriate. (i.e., Do you feel the scale provided you with an appropriate way to respond?)		
Suggested revisions:		
3.2. How severe is the discomfort (aching, cramping, sore, uncomfortable, stiff, dull, pressure, burning, or shooting) you experience with the following laptop transportation methods?	**YES**	**NO**
The question is clear and understandable. (i.e., Do you have to read the item more than one to understand what it is asking?)		
Suggested revisions:		

The example is clear and appropriate.		
Suggested revisions:		
The scale is appropriate. (i.e., Do you feel the scale provided you with an appropriate way to respond?)		
Suggested revisions:		
3.3. What devices do you typically <u>take</u> when carrying your laptop computer?	**YES**	**NO**
The question is clear and understandable. (i.e., Do you have to read the item more than one to understand what it is asking?)		
Suggested revisions:		
The example is clear and appropriate.		
Suggested revisions:		
The scale is appropriate. (i.e., Do you feel the scale provided you with an appropriate way to respond?)		
Suggested revisions:		
The order of questions (item 3.1, 3.2, and 3.3) is clear. (i.e., Do you get confused as to which question to go to next?)		
Suggested revisions:		
Additional questions are needed in the Section 3.		
Items needed to be added in the Section 3:		

Section 4: Laptop Related Tasks		
4.1. What type of tasks do you do the most often when using your laptop computer?	**YES**	**NO**
The question is clear and understandable.		
Suggested revisions:		
The example is clear and appropriate.		
Suggested revisions:		
The scale is appropriate. (i.e., Do you feel the scale provided you with an appropriate way to respond?)		
Suggested revisions:		
Additional questions are needed in the Section 4.		
Items needed to be added in the Section 4:		
Section 5: Laptop Specifications		
5.1. What model of laptop computer do you typically use?	**YES**	**NO**
The question is clear and understandable.		
Suggested revisions:		
The example is clear and appropriate.		
Suggested revisions:		
The scale is appropriate. (i.e., Do you feel the scale provided you with an appropriate way to respond?)		
Suggested revisions:		

5.2. What type of input device(s) do you <u>use</u> with your laptop computer?	**YES**	**NO**
The question is clear and understandable.		
Suggested revisions:		
The example is clear and appropriate.		
Suggested revisions:		
The scale is appropriate. (i.e., Do you feel the scale provided you with an appropriate way to respond?)		
Suggested revisions:		

5.3. What type of other device(s) do you use besides your laptop computer?	**YES**	**NO**
The question is clear and understandable.		
Suggested revisions:		
The example is clear and appropriate.		
Suggested revisions:		
The scale is appropriate. (i.e., Do you feel the scale provided you with an appropriate way to respond?)		
Suggested revisions:		

5.4. How much does your laptop weigh, including battery?	**YES**	**NO**
The question is clear and understandable.		
Suggested revisions:		

The example is clear and appropriate.		
Suggested revisions:		
The scale is appropriate. (i.e., Do you feel the scale provided you with an appropriate way to respond?)		
Suggested revisions:		
5.5. What is your laptop monitor size?	**YES**	**NO**
The question is clear and understandable.		
Suggested revisions:		
The example is clear and appropriate.		
Suggested revisions:		
The scale is appropriate. (i.e., Do you feel the scale provided you with an appropriate way to respond?)		
Suggested revisions:		
The order of questions (item 5.1, 5.2, 5.3, and 5.5) is clear. (i.e., Do you get confused as to which question to go to next?)		
Suggested revisions:		
Additional questions are needed in the Section 5.		
Items needed to be added in the Section 5:		

Section 6: Usage Time		
6.1. What percentage of <u>computing time</u> during a week do you spend working on a laptop and a desktop computer?	**YES**	**NO**
The question is clear and understandable.		
Suggested revisions:		
The example is clear and appropriate.		
Suggested revisions:		
The scale is appropriate. (i.e., Do you feel the scale provided you with an appropriate way to respond?)		
Suggested revisions:		
6.2. On average, how many years have you used <u>any</u> laptop computer?	**YES**	**NO**
The question is clear and understandable.		
Suggested revisions:		
The example is clear and appropriate.		
Suggested revisions:		
The scale is appropriate. (i.e., Do you feel the scale provided you with an appropriate way to respond?)		
Suggested revisions:		
6.3. On average, how many hours per day do you use <u>any</u> laptop computer?	**YES**	**NO**
The question is clear and understandable.		
Suggested revisions:		

The example is clear and appropriate.		
Suggested revisions:		
The scale is appropriate. (i.e., Do you feel the scale provided you with an appropriate way to respond?)		
Suggested revisions:		
6.4. On average, how long do you work on your laptop computer without breaks?	**YES**	**NO**
The question is clear and understandable.		
Suggested revisions:		
The example is clear and appropriate.		
Suggested revisions:		
The scale is appropriate. (i.e., Do you feel the scale provided you with an appropriate way to respond?)		
Suggested revisions:		
6.5. On average, how often do you take a rest break during laptop computing?	**YES**	**NO**
The question is clear and understandable.		
Suggested revisions:		
The example is clear and appropriate.		
Suggested revisions:		

The scale is appropriate. (i.e., Do you feel the scale provided you with an appropriate way to respond?)		
Suggested revisions:		
6.6. How many minutes is typical rest break during laptop computing?	**YES**	**NO**
The question is clear and understandable.		
Suggested revisions:		
The example is clear and appropriate.		
Suggested revisions:		
The scale is appropriate. (i.e., Do you feel the scale provided you with an appropriate way to respond?)		
Suggested revisions:		
The order of questions (item 6.1, 6.2, 6.3, 6.4, 6.5, and 6.6) is clear. (i.e., Do you get confused as to which question to go to next?)		
Suggested revisions:		
Additional questions are needed in the Section 6.		
Items needed to be added in the Section 6:		
Section 7: Laptop Workstation Setup		
7.1. What are your TYPICAL workstation setups during laptop computing?	**YES**	**NO**
The question is clear and understandable.		
Suggested revisions:		
The example is clear and appropriate.		
Suggested revisions:		

The scale is appropriate. (i.e., Do you feel the scale provided you with an appropriate way to respond?)		
Suggested revisions:		
7.2. How severe is the discomfort (aching, cramping, sore, uncomfortable, stiff, dull, pressure, burning, or shooting) you experience with the following laptop workstation setups?	**YES**	**NO**
The question is clear and understandable.		
Suggested revisions:		
The example is clear and appropriate.		
Suggested revisions:		
The scale is appropriate. (i.e., Do you feel the scale provided you with an appropriate way to respond?)		
Suggested revisions:		
7.3. What is your most COMFORTABLE laptop workstation setup during laptop computing?	**YES**	**NO**
The question is clear and understandable.		
Suggested revisions:		
The example is clear and appropriate.		
Suggested revisions:		
The scale is appropriate. (i.e., Do you feel the scale provided you with an appropriate way to respond?)		
Suggested revisions:		

The order of questions (item 7.1, 7.2, and 7.3) is clear. (i.e., Do you get confused as to which question to go to next?)		
Suggested revisions:		
Additional questions are needed in the Section 7.		
Items needed to be added in the Section 7:		
Section 8: Overall Laptop Related Discomfort		
8.1. Have you ever experienced discomfort in your neck, shoulders, arms, hands, wrists, upper back, and trunk, during laptop computing?	**YES**	**NO**
The question is clear and understandable.		
Suggested revisions:		
The example is clear and appropriate.		
Suggested revisions:		
The scale is appropriate. (i.e., Do you feel the scale provided you with an appropriate way to respond?)		
Suggested revisions:		
8.2. How severe is the discomfort you <u>usually</u> experience when working on a laptop computer?	**YES**	**NO**
The question is clear and understandable.		
Suggested revisions:		
The example is clear and appropriate.		
Suggested revisions:		

The scale is appropriate. (i.e., Do you feel the scale provided you with an appropriate way to respond?)		
Suggested revisions:		
The order of questions (item 8.1 and 8.2) is clear. (i.e., Do you get confused as to which question to go to next?)		
Suggested revisions:		
Additional questions are needed in the Section 8.		
Items needed to be added in the Section 8:		
Section 9: Previous/Current Health Status		
9.1. Have you ever been diagnosed or treated by a doctor for pain/discomfort in your neck, shoulders, arms, hands, wrists, or trunk?	**YES**	**NO**
The question is clear and understandable.		
Suggested revisions:		
The example is clear and appropriate.		
Suggested revisions:		
The scale is appropriate. (i.e., Do you feel the scale provided you with an appropriate way to respond?)		
Suggested revisions:		
9.2. What type of diagnosis did you receive from a doctor?	**YES**	**NO**
The question is clear and understandable.		
Suggested revisions:		

The example is clear and appropriate.		
Suggested revisions:		
The scale is appropriate. (i.e., Do you feel the scale provided you with an appropriate way to respond?)		
Suggested revisions:		
9.3. Do you smoke cigarette?	**YES**	**NO**
The question is clear and understandable.		
Suggested revisions:		
The example is clear and appropriate.		
Suggested revisions:		
The scale is appropriate. (i.e., Do you feel the scale provided you with an appropriate way to respond?)		
Suggested revisions:		
9.4. On average, how many cigarettes did you smoke each day?	**YES**	**NO**
The question is clear and understandable.		
Suggested revisions:		
The example is clear and appropriate.		
Suggested revisions:		
The scale is appropriate. (i.e., Do you feel the scale provided you with an appropriate way to respond?)		
Suggested revisions:		

9.5. Do you use other forms of tobacco, other than cigarettes?	**YES**	**NO**
The question is clear and understandable.		
Suggested revisions:		
The example is clear and appropriate.		
Suggested revisions:		
The scale is appropriate. (i.e., Do you feel the scale provided you with an appropriate way to respond?)		
Suggested revisions:		
9.6. Is your vision corrected?	**YES**	**NO**
The question is clear and understandable.		
Suggested revisions:		
The example is clear and appropriate.		
Suggested revisions:		
The scale is appropriate. (i.e., Do you feel the scale provided you with an appropriate way to respond?)		
Suggested revisions:		
9.7. In general, how would you describe your overall physical health?	**YES**	**NO**
The question is clear and understandable.		
Suggested revisions:		
The example is clear and appropriate.		
Suggested revisions:		

The scale is appropriate. (i.e., Do you feel the scale provided you with an appropriate way to respond?)		
Suggested revisions:		
9.8. Compared to one year ago, how would you rate your overall physical health?	**YES**	**NO**
The question is clear and understandable.		
Suggested revisions:		
The example is clear and appropriate.		
Suggested revisions:		
The scale is appropriate. (i.e., Do you feel the scale provided you with an appropriate way to respond?)		
Suggested revisions:		
The order of questions (item 9.1, 9.2, 9.3, 9.4, 9.5, 9.6, 9.7, and 9.8) is clear. (i.e., Do you get confused as to which question to go to next?)		
Suggested revisions:		
Additional questions are needed in the Section 9.		
Items needed to be added in the Section 9:		
Section 10: Recreational Activities		
10.1. During an average <u>week</u>, how many hours do you spend on the following activities?	**YES**	**NO**
The question is clear and understandable.		
Suggested revisions:		

The example is clear and appropriate.		
Suggested revisions:		
The scale is appropriate. (i.e., Do you feel the scale provided you with an appropriate way to respond?)		
Suggested revisions:		
Additional questions are needed in the Section 10.		
Items needed to be added in the Section 10:		
Section 11: Student Health Related Role Functioning		
11.1. In the past 2 weeks, how much difficulty have you had with the following activities as a result of discomfort in your hands, wrists, arms, shoulders, back, or neck?	**YES**	**NO**
The question is clear and understandable.		
Suggested revisions:		
The example is clear and appropriate.		
Suggested revisions:		
The scale is appropriate. (i.e., Do you feel the scale provided you with an appropriate way to respond?)		
Suggested revisions:		
Additional questions are needed in the Section 11.		
Items needed to be added in the Section 11:		

Section 12: Attitude Toward the Laptop Computer		
12.1. In this section, we are interested in your general attitude toward the laptop computer. How much do you agree or disagree with the following statements?	**YES**	**NO**
The question is clear and understandable.		
Suggested revisions:		
The example is clear and appropriate.		
Suggested revisions:		
The scale is appropriate. (i.e., Do you feel the scale provided you with an appropriate way to respond?)		
Suggested revisions:		
Additional questions are needed in the Section 12.		
Items needed to be added in the Section 12:		

Review of the Survey Design

General Survey Design	Yes	No
The font size is big enough to be read easily by respondents.		
Suggested revisions:		
The length of the survey is appropriate. (Estimated time needed to complete the survey is 20 – 30 minutes).		
Suggested revisions:		
The survey format flow is effective.		
Suggested revisions:		

Additional Recommendations for Improving the Quality of the Survey

Thank you again for sharing your knowledge and expertise in the validation process of the survey development.

APPENDIX B

SUMMARY OF THE FEEDBACKS RAISED BY THE EXPERT REVIEWERS

Specific Concerns Raised by the Expert Reviewers

in the Validation Process of the LCUSS Development

Submitted to: Expert Reviewers

Submitted by: Hyekyoung Shin

Thank you for sharing your expertise and opinion in the validation process of the survey instrument development (i.e., Laptop Computer User Screening Survey; LCUSS). Based on your feedback, I modified and finalized the items and designs of the LCUSS. The specific concerns below were also reflected in final version of the LCUSS.

LCUSS Expert Panel Evaluation Form

The targeted respondent for the LCUSS will be college students. Please circle "Yes" or "No" for each of the questions below. If answer is no, please provide which items need to modify and then suggest revisions to these items.

<u>Review of the Survey Items</u>

Section 1: Demographic Information	**YES**	**NO**
The questions are clear and understandable.		**X**
Items needed to be modified and suggested revisions: <u>From Dr. Holm</u> • "college" should be "university" • Item 1.3: Change "or" to "and" / "inch" to "inches"		

From Dr. Raina • Item 1.2: Change “sex” to “gender” • Item 1.3: Height is generally indicated as ____ft_____inches (e.g., 5' 3")		
The example is clear and appropriate.		X
Items needed to be modified and suggested revisions: From Dr. Holm • Item 1.14: Include “university graduate house” as an additional example From Dr. Baker • Item 1.14: Change “off-campus room or apartment” to “off-campus room/different from a rented apartment” From Dr. Raina • Item 1.14: Not clear the difference between “off-campus room or apartment” and “rented apartment or house” From Young-Joo Item 1.12: Ask the duration of attendance for graduate school		
The scale is appropriate.		X
Items needed to be modified and suggested revisions: From Krissy • Item 1.5: Change “check one” to “check more than one race” • Item 1.8: Break out the single category into separate categories From Young-Joo • Item 1.8: Break out the single category into separate categories		
The order of questions is clear.		X
Items needed to be modified and suggested revisions: From Young-Joo • Item 1.5 and 1.6: Change the order between Item 1.5 and 1.6		
Additional questions are not needed in the Section 1.	X	
Items needed to be added in the Section 1:		
Section 2: Location of Laptop Computer Use		
2.1. Where do you use the laptop computer?	**YES**	**NO**
The question is clear and understandable.		X
Suggested revisions: From Dr. Holm • “the laptop computer” should be “your laptop computer” From Young-Joo • Not clear “your laptop computer” if it means all sort of laptop computers		
The example is clear and appropriate.		X
Suggested revisions:		

<u>From Dr. Holm</u> • Wrong word (“lap” to “lab”) <u>From Dr. Baker</u> • Include “restaurant or other eating place” and “outdoors” • Wrong word (“lap” to “lab”) <u>From Dr. Raina</u> • Wrong word (“lap” to “lab”)		
The scale is appropriate.		X
Suggested revisions: <u>From Dr. Raina</u> • Include more space for “others”		
2.2. What is the reason for selection of location to use your laptop computer?	**YES**	**NO**
The question is clear and understandable.		X
Suggested revisions: <u>From Dr. Holm</u> • “to use the laptop computer” should be “for use of your laptop computer” <u>From Krisssy</u> • Change to “Please rank the following options from the most important (1) to the least important (5) for selecting location for your laptop computer use”		
The example is clear and appropriate.		X
Suggested revisions: <u>From Dr. Holm</u> • “presence of charge connection” should be “electrical outlet” • Include “comfortable chair” <u>From Dr. Baker</u> • “presence of table” are similar with “presence of chair and desk” <u>From Dr. Raina</u> • “charge connection” should be “wall outlet” • Clarify “Location is convenient”		
The scale is appropriate.	X	
Suggested revisions:		
The order of questions (item 2.1 and 2.2) is clear.	X	
Suggested revisions:		
Additional questions are needed in the Section 2.	X	
Items needed to be added in the Section 2:		

Section 3: Laptop Transportation Methods		
3.1. How do you carry your laptop computer?	**YES**	**NO**
The question is clear and understandable.	X	
Suggested revisions:		
The example is clear and appropriate.		X
Suggested revisions: From Dr. Holm • "Handed bag or briefcase" should be "Bag or briefcase with handle" • "Rolling pull cart or wheeled cart bag" should be "Rolling backpack or briefcase" • "In a backpack" should be "in your backpack" From Dr. Baker • "Rolling pull cart or wheeled cart bag" should be "Rolling bag or briefcase" From Dr. Raina • Wrong word ("lap" to "lab") • "Handed bag or briefcase" should be "Bag or briefcase with handles" • "Rolling pull cart or wheeled cart bag" should be "Rolling pull cart or bag with wheels"		
The scale is appropriate.	X	
Suggested revisions:		
3.2. How severe is the discomfort (aching, cramping, sore, uncomfortable, stiff, dull, pressure, burning, or shooting) you experience with the following laptop transportation methods?	**YES**	**NO**
The question is clear and understandable.		X
Suggested revisions: From Dr. Baker • "Please circle one answer for each line" should be "Please circle one number for each line" From Krissy • Change to "soreness, uncomfortableness, stiffness, dullness"		
The example is clear and appropriate.		X
Suggested revisions: From Dr. Holm • Match example with item 3.1 From Dr. Baker • Match example with item 3.1 From Dr. Raina • Match example with item 3.1 • Include "Other" to match with item 3.1 • Move the number "0" to the left		

From Krissy • Change to "if other method specified above" From Young-Joo • Define "worst discomfort"		
The scale is appropriate.	X	
Suggested revisions:		
3.3. What devices do you typically take when carrying your laptop computer?	**YES**	**NO**
The question is clear and understandable.		X
Suggested revisions: From Dr. Holm • "AC adaptor" should be "AC adapter"		
The example is clear and appropriate.	X	
Suggested revisions:		
The scale is appropriate.	X	
Suggested revisions:		
The order of questions (item 3.1, 3.2, and 3.3) is clear.		X
Suggested revisions: From Krissy • Put the item 3.3 before item 3.2 as if they are adding other devices to laptop bag. These devices affect to the discomfort level.		
Additional questions are not needed in the Section 3.	X	
Items needed to be added in the Section 3:		
Section 4: Laptop Related Tasks		
4.1. What type of tasks do you do the most when using your laptop computer?	**YES**	**NO**
The question is clear and understandable.		X
Suggested revisions: From Dr. Holm • "the most" should be "most often" • "Please select the top three activities and make up to three priorities" should be "Please rank the top 3 activities (1=most frequent; 2=next most frequent, etc.)" From Dr. Baker • Not clear about 3 priorities		

From Dr. Raina • Not clear "make up to three priorities" From Krissy • "Please rank the top 3 activities " should be "Choose your top 3 activities and rank each activity"		
The example is clear and appropriate.		X
Suggested revisions: From Dr. Holm • Include "look up contacts (addresses or phone numbers)," "course web or online courses," and "library search" • Delete "school research or courses" From Dr. Raina • Not clear the difference between "check news, weather, sports" and "web surfing"		
The scale is appropriate.	X	
Suggested revisions:		
Additional questions are not needed in the Section 4.	X	
Items needed to be added in the Section 4:		
Section 5: Laptop Specifications		
5.1. What model of laptop computer do you typically use?	**YES**	**NO**
The question is clear and understandable.		X
Suggested revisions: From Young-Joo • Not clear if the laptop means frequently used one or one of the laptop computers		
The example is clear and appropriate.	X	
Suggested revisions:		
The scale is appropriate.	X	
Suggested revisions:		
5.2. What type of input device(s) do you <u>use</u> with your laptop computer?	**YES**	**NO**
The question is clear and understandable.	X	
Suggested revisions:		
The example is clear and appropriate.		X
Suggested revisions: From Krissy		

• Add an N/A category		
The scale is appropriate.	X	
Suggested revisions:		
5.3. What type of other device(s) do you use besides your laptop computer?	**YES**	**NO**
The question is clear and understandable.	X	
Suggested revisions:		
The example is clear and appropriate.		X
Suggested revisions: From Krissy • Include N/A category		
The scale is appropriate.	X	
Suggested revisions:		
5.4. How much does your laptop weigh, including battery?	**YES**	**NO**
The question is clear and understandable.		X
Suggested revisions: From Dr. Holm • "weight" should be "weigh" From Dr. Baker • "weight" should be "weigh" From Krissy • A both 5.2 and 5.3 are looking at input devices, so put together		
The example is clear and appropriate.		X
Suggested revisions: From Krissy • Add an NA category		
The scale is appropriate.	X	
Suggested revisions:		
5.5. What is your laptop monitor size?	**YES**	**NO**
The question is clear and understandable.	X	
Suggested revisions:		
The example is clear and appropriate.	X	
Suggested revisions:		

The scale is appropriate.	X	
Suggested revisions:		
The order of questions (item 5.1, 5.2, 5.3, and 5.4) is clear.	X	
Suggested revisions:		
Additional questions are not needed in the Section 5.		• X
Items needed to be added in the Section 5: From Dr. Holm • Include additional question if students use other devices with their laptop computers (webcam, speakers, microphone)		
Section 6: Usage Time		
6.1. What percentage of computing time during a week do you spend working on a laptop and a desktop computer?	**YES**	**NO**
The question is clear and understandable.	X	
Suggested revisions:		
The example is clear and appropriate.	X	
Suggested revisions:		
The scale is appropriate.	X	
Suggested revisions:		
6.2. On average, how many years have you used any laptop computer?	**YES**	**NO**
The question is clear and understandable.	X	
Suggested revisions:		
The example is clear and appropriate.		X
Suggested revisions: From Dr. Baker • "year" should be "years"		
The scale is appropriate.	X	
Suggested revisions:		
6.3. On average, how many hours per day do you use any laptop computer?	**YES**	**NO**

The question is clear and understandable.	X	
Suggested revisions:		
The example is clear and appropriate.		X
Suggested revisions: From Dr. Holm • Include "minutes"		
The scale is appropriate.	X	
Suggested revisions:		
6.4. On average, how long do you work on your laptop computer without breaks?	**YES**	**NO**
The question is clear and understandable.		X
Suggested revisions: From Young-Joo • Overlap with item 6.5		
The example is clear and appropriate.		X
Suggested revisions: From Dr. Holm • Include "minutes"		
The scale is appropriate.	X	
Suggested revisions:		
6.5. On average, how often do you take a rest break during laptop computing?	**YES**	**NO**
The question is clear and understandable.		X
Suggested revisions: From Young-Joo • Overlap with item 6.4		
The example is clear and appropriate.	X	
Suggested revisions:		
The scale is appropriate.		X
Suggested revisions: From Dr. Holm • Change the scales with ½ hour intervals From Dr. Raina		

• Change the scales with ½ hour intervals		
6.6. How many minutes is typical rest break during laptop computing?	**YES**	**NO**
The question is clear and understandable.	X	
Suggested revisions:		
The example is clear and appropriate.	X	
Suggested revisions:		
The scale is appropriate.		X
Suggested revisions: From Dr. Holm • Change the scales with 5 min intervals		
The order of questions (item 6.1, 6.2, 6.3, 6.4, 6.5, and 6.6) is clear.	X	
Suggested revisions:		
Additional questions are not needed in the Section 6.	X	
Items needed to be added in the Section 6:		
Section 7: Laptop Workstation Setup		
7.1. What are your TYPICAL workstation setups during laptop computing?	**YES**	**NO**
The question is clear and understandable.		X
Suggested revisions: From Dr. Holm • "figure" should be "figures" From Dr. Raina • "postures" should be "posture"		
The example is clear and appropriate.	X	
Suggested revisions:		
The scale is appropriate.	X	
Suggested revisions:		
7.2. How severe is the discomfort (aching, cramping, sore, uncomfortable, stiff, dull, pressure, burning, or shooting) you experience with the following laptop workstation setups?	**YES**	**NO**
The question is clear and understandable.		X
Suggested revisions:		

<table>
<tr><td colspan="3">From Dr. Holm
“transportation methods” should be “computing postures”
From Dr. Baker
“transportation methods” should be “postures”</td></tr>
<tr><td>The example is clear and appropriate.</td><td></td><td>X</td></tr>
<tr><td colspan="3">Suggested revisions:
From Dr. Holm
Include “Other” to match with item 7.1
From Dr. Raina
Include “Other” to match with item 7.1
From Krissy
Change to “if other posture specified above”</td></tr>
<tr><td>The scale is appropriate.</td><td></td><td>X</td></tr>
<tr><td colspan="3">Suggested revisions:
From Dr. Baker
“Please circle one answer for each line” should be “Please circle one number for each line”
From Dr. Raina
Include the option for “NA” (“not applicable” is not the same with “no discomfort”)</td></tr>
<tr><th>7.3. What is your most COMFORTABLE laptop workstation setup during laptop computing?</th><th>YES</th><th>NO</th></tr>
<tr><td>The question is clear and understandable.</td><td></td><td>X</td></tr>
<tr><td colspan="3">Suggested revisions:
From Dr. Holm
“from your most comfortable (1) to the least (6)” should be “for your most comfortable(1) to your least comfortable postures (6)”</td></tr>
<tr><td>The example is clear and appropriate.</td><td></td><td>X</td></tr>
<tr><td colspan="3">Suggested revisions:
From Dr. Baker
Match examples with item 7.1</td></tr>
<tr><td>The scale is appropriate.</td><td></td><td>X</td></tr>
<tr><td colspan="3">Suggested revisions:
From Dr. Raina
Include the option for “NA”
From Krissy
Include the option for “NA”
From Young-Joo
Include the option for “NA”</td></tr>
<tr><td>The order of questions (item 7.1, 7.2, and 7.3) is clear.</td><td>X</td><td></td></tr>
<tr><td colspan="3">Suggested revisions:</td></tr>
</table>

Additional questions are not needed in the Section 7.	X	
Items needed to be added in the Section 7:		
Section 8: Overall Laptop Related Discomfort		
8.1. Have you ever experienced discomfort in your neck, shoulders, arms, hands, wrists, upper back, and trunk, during laptop computing?	**YES**	**NO**
The question is clear and understandable.	X	
Suggested revisions:		
The example is clear and appropriate.		X
Suggested revisions: From Dr. Holm • "No" answer should be first.		
The scale is appropriate.	X	
Suggested revisions:		
8.2. How severe is the discomfort you usually experience when working on a laptop computer?	**YES**	**NO**
The question is clear and understandable.		X
Suggested revisions: From Dr. Baker • "presently" should be "usually"		
The example is clear and appropriate.	X	
Suggested revisions:		
The scale is appropriate.	X	
Suggested revisions:		
The order of questions (item 8.1 and 8.2) is clear.	X	
Suggested revisions:		
Additional questions are not needed in the Section 8.	X	
Items needed to be added in the Section 8:		
Section 9: Previous/Current Health Status		
9.1. Have you ever been diagnosed or treated by a doctor for pain/discomfort in your neck, shoulders, arms, hands, wrists, or trunk?	**YES**	**NO**

The question is clear and understandable.	X	
Suggested revisions:		
The example is clear and appropriate.		X
Suggested revisions: <u>From Dr. Holm</u> • "No" answer should be first.		
The scale is appropriate.	X	
Suggested revisions:		
9.2. What type of diagnosis did you receive from a doctor?	**YES**	**NO**
The question is clear and understandable.		X
Suggested revisions: <u>From Dr. Holm</u> • "received" should be "receive" <u>From Dr. Raina</u> • "received" should be "receive" • Delete "treatment"		
The example is clear and appropriate.		X
Suggested revisions: <u>From Dr. Holm</u> • "ligament stain" should be "ligament strain" <u>From Dr. Raina</u> • "stain" should be "strain" • Check "tendonitis"		
The scale is appropriate.	X	
Suggested revisions:		
9.3. Do you smoke cigarette?	**YES**	**NO**
The question is clear and understandable.		X
Suggested revisions: <u>From Krissy</u> • "cigarette" should be "cigarettes"		
The example is clear and appropriate.		X
Suggested revisions: <u>From Dr. Holm</u> • Include "pipe" and "chewing tobacco"		

The scale is appropriate.	X	
Suggested revisions:		
9.4. On average, how many cigarettes did you smoke each day?	**YES**	**NO**
The question is clear and understandable.		X
Suggested revisions: From Krissy • "did" should be "do" From Young-Joo • "did" should be "do"		
The example is clear and appropriate.	X	
Suggested revisions:		
The scale is appropriate.	X	
Suggested revisions:		
9.5. Do you use other forms of tobacco, other than cigarettes?	**YES**	**NO**
The question is clear and understandable.	X	
Suggested revisions:		
The example is clear and appropriate.	X	
Suggested revisions:		
The scale is appropriate.		
Suggested revisions:		
9.6. Is your vision corrected?	**YES**	**NO**
The question is clear and understandable.	X	
Suggested revisions:		
The example is clear and appropriate.		X
Suggested revisions: From Dr. Holm • Include "corrected with surgery"		
The scale is appropriate.	X	
Suggested revisions:		

9.7. In general, how would you describe your overall physical health?	**YES**	**NO**
The question is clear and understandable.	X	
Suggested revisions:		
The example is clear and appropriate.	X	
Suggested revisions:		
The scale is appropriate.	X	
Suggested revisions:		
9.8. Compared to one year ago, how would you rate your overall physical health in general now?	**YES**	**NO**
The question is clear and understandable.	X	
Suggested revisions:		
The example is clear and appropriate.	X	
Suggested revisions:		
The scale is appropriate.	X	
Suggested revisions:		
The order of questions (item 9.1, 9.2, 9.3, 9.4, 9.5, and 9.6) is clear.	X	
Suggested revisions:		
Additional questions are not needed in the Section 9.	X	
Items needed to be added in the Section 9:		
Section 10: Recreational Activities		
10.1. During an average week, how many hours do you spend on the following activities?	**YES**	**NO**
The question is clear and understandable.	X	
Suggested revisions:		
The example is clear and appropriate.		X
Suggested revisions: From Dr. Holm • "lifting objects" should be "lifting weights" • "assorting" should be "sorting" • "lifting carrying groceries, box or books" should be "lifting or carrying groceries,		

boxes, or books" From Dr. Baker • "assorting" should be "sorting" • "lifting carrying groceries, box or books" should be " lifting or carrying objects, such as groceries, boxes, or books" From Dr. Raina • "assorting" should be "sorting" • Include "or" between "lifting" and "carrying"		
The scale is appropriate.	X	
Suggested revisions:		
Additional questions are not needed in the Section 10.	X	
Items needed to be added in the Section 10:		
Section 11: Health Related Functional role		
11.1. In the past 2 weeks, how much difficulty have you had with the following activities as a result of discomfort in your hands, wrist, arms, shoulder, back, or neck?	**YES**	**NO**
The question is clear and understandable.		X
Suggested revisions: From Dr. Baker • "If not applicable with the activity" should be "If not applicable"		
The example is clear and appropriate.		X
Suggested revisions: From Dr. Holm • "lifting objects" should be "lifting weights" • "lifting carrying groceries, box or books" should be "lifting or carrying groceries, boxes, or books" • "so difficulty" should be "so difficult" From Dr. Baker • "assignment" should be "assignments" From Dr. Raina • "assorting" should be "sorting" • "lifting objects" should be "lifting weights" • Include "NA" box		
The scale is appropriate.	X	
Suggested revisions:		
Additional questions are not needed in the Section 11.	X	
Items needed to be added in the Section 11:		

Section 12: Attitude Toward the Laptop Computer		
12.1. In this section, we are interested in your general attitude toward the laptop computer. How much do you agree or disagree with the following statement?	**YES**	**NO**
The question is clear and understandable.	X	
Suggested revisions:		
The example is clear and appropriate.		X
Suggested revisions: From Dr. Holm • "Strongly disagree" should be "strongly agree"		
The scale is appropriate.	X	
Suggested revisions:		
Additional questions are not needed in the Section 12.	X	
Items needed to be added in the Section 12:		

Review of the Survey Design

General survey design	**Yes**	**No**
The font size is big enough to be read easily by respondents.	X	
Suggested revisions:		
The length of the survey is appropriate. (Estimated time needed to complete the survey is 20 – 30 minutes).	X	
Suggested revisions:		
The survey format flow is effective.		X
Suggested revisions: From Krissy • Item 9.3-9.8 should move to end of survey or even perhaps to beginning when gathering other demographic information		

Additional Recommendations for Improving the Quality of the Survey

From Dr. Holm

- In front of each response, put the data entry number
-

Thank you again for sharing your knowledge and expertise in the validation process of the survey development.

APPENDIX C

TEST-RETEST RELIABILITY OF THE LCUSS: INTRA-CLASS CORRELATION ANALYSIS OF THE LCUSS

#	LCUSS items	ICCs	95% CI		*p*
		Single measures	Lower	Upper	
2.1	% Location – Library	0.93	0.81	0.98	< **.001**
	% Location – Campus classroom	1.00	1.00	1.00	< **.001**
	% Location – Campus computer lab	0.76	0.43	0.91	< **.001**
	% Location – Home	0.83	0.57	0.94	< **.001**
	% Location – Café or restaurant	0.95	0.87	0.98	< **.001**
	% Location – Outdoor places	0.89	0.69	0.96	< **.001**
	% Location – Transportation	0.62	0.17	0.85	**.01**
	% Location – Office	0.76	0.42	0.91	< **.001**
	% Location – Friend's house	1.00	1.00	1.00	< **.001**
3.3	Discomfort – Bag or briefcase with handle	0.56	0.09	0.83	**.01**
	Discomfort – Over the shoulder bag	0.61	0.16	0.85	**.01**
	Discomfort – Rolling bag or briefcase	0.01	-0.49	0.51	.49
	Discomfort – In your backpack	0.91	0.76	0.97	< **.001**
6.1	% laptop computer usage time	0.94	0.83	0.98	< **.001**
	% desktop computer usage time	0.94	0.83	0.98	< **.001**
6.2	Length of years having a laptop computer	0.99	0.97	1.00	< **.001**
6.3	Duration of daily laptop computer use	0.92	0.78	0.97	< **.001**
6.4	Duration of continuous laptop computer use	0.74	0.38	0.90	< **.001**

Table (Continued).

#	LCUSS items	ICCs	95% CI		*p*
		Single measures	Lower	Upper	
7.1	% Posture – Desktop sitting	0.98	0.95	0.99	< **.001**
	% Posture – Lying prone	0.85	0.61	0.95	< **.001**
	% Posture – Lying supine	0.97	0.93	0.99	< **.001**
	% Posture – Floor sitting	0.98	0.94	0.99	< **.001**
	% Posture – Chair sitting	0.97	0.91	0.99	< **.001**
	% Posture – Lap sitting	1.00	0.99	1.00	< **.001**
7.2	Discomfort – Desktop sitting	0.79	0.48	0.92	< **.001**
	Discomfort – Lying prone	0.96	0.90	0.99	< **.001**
	Discomfort – Lying supine	0.80	0.50	0.93	< **.001**
	Discomfort – Floor sitting	0.81	0.53	0.93	< **.001**
	Discomfort – Chair sitting	0.54	0.06	0.82	**.02**
	Discomfort – Lap sitting	0.79	0.48	0.92	< **.001**
8.2	Overall discomfort – Neck	0.93	0.82	0.98	< **.001**
	Overall discomfort – Rt. shoulder	0.84	0.58	0.94	< **.001**
	Overall discomfort – Lt. shoulder	0.81	0.53	0.93	< **.001**
	Overall discomfort – Rt. upper arm	0.54	0.06	0.82	**.02**
	Overall discomfort – Lt. upper arm	0.53	0.05	0.81	**.02**
	Overall discomfort – Rt. lower arm	0.66	0.24	0.87	< **.001**
	Overall discomfort – Lt. lower arm	0.81	0.53	0.93	< **.001**
	Overall discomfort – Rt. hand/wrist	0.85	0.62	0.95	< **.001**
	Overall discomfort – Lt. hand/wrist	0.92	0.78	0.97	< **.001**
	Overall discomfort – Upper back	0.97	0.90	0.99	< **.001**
	Overall discomfort – Lower back	0.93	0.81	0.98	< **.001**

Note. ICCs = Intra-class correlation coefficients; CI = Confidence interval; Rt. = Right; Lt. = Left; Bold indicates significant items

APPENDIX D

TEST-RETEST RELIABILITY OF THE LCUSS: KAPPA STATISTICS OF THE LCUSS

#	LCUSS items	Kappa	*p*
2.2	Accessibility of wireless internet	0.65	**< .001**
	Presence of electrical outlet	1.00	**< .001**
	Presence of chair and desk	0.60	**< .001**
	presence of comfortable chair	0.73	**< .001**
	Location is convenient	0.66	**< .001**
	Size or weight of laptop	1.00	**< .001**
3.1	Carrying type: Bag with handle	0.71	**< .001**
	Carrying type: Over the shoulder bag	0.73	**.01**
	Carrying type: Rolling bag	1.00	**< .001**
	Carrying type: In your backpack	1.00	**< .001**
3.2	Carrying device: External mouse	0.61	**.01**
	Carrying device: AC adapter	1.00	**< .001**
	Carrying device: External battery	1.00	**< .001**
	Carrying device: External keyboard	1.00	**< .001**
	Carrying device: External disk drive	0.63	**.01**
	Carrying device: Extension cord	1.00	**< .001**

Table (Continued).

#	LCUSS items	Kappa	*p*
4.1	Laptop related tasks: Word processing	0.73	< **.001**
	Laptop related tasks: Presentation	1.00	< **.001**
	Laptop related tasks: Analysis or spreadsheets	1.00	< **.001**
	Laptop related tasks: CourseWeb	0.85	< **.001**
	Laptop related tasks: Library search	1.00	< **.001**
	Laptop related tasks: Web surfing	1.00	< **.001**
	Laptop related tasks: Scheduling	1.00	< **.001**
	Laptop related tasks: Look up contacts	1.00	< **.001**
	Laptop related tasks: Communication	1.00	< **.001**
	Laptop related tasks: Shopping	1.00	< **.001**
	Laptop related tasks: Check news, weather	1.00	< **.001**
	Laptop related tasks: Check email	1.00	< **.001**
	Laptop related tasks: Watch movies or videos	1.00	< **.001**
	Laptop related tasks: Pay bills	1.00	< **.001**
	Laptop related tasks: Play games	1.00	< **.001**
5.1	Laptop model	1.00	< **.001**
5.2	Input device: Mouse	0.67	**.01**
	Input device: Trackball	1.00	< **.001**
	Input device: Joystick	1.00	< **.001**
	Input device: Touch pad	0.67	**.01**
	Input device: Track point	0.44	**.04**
	Input device: Keyboard	0.33	.09
	Input device: Numeric keypad	1.00	< **.001**
5.3	Other device: Webcam	1.00	< **.001**
	Other device: Speakers	1.00	< **.001**
	Other device: Microphones	1.00	< **.001**
	Other device: Earphone	0.60	**.01**
5.4	Laptop weight	1.00	< **.001**
5.5	Monitor size	1.00	< **.001**
6.5	Typical rest break	1.00	< **.001**

Table (Continued).

#	LCUSS items	Kappa	*p*
7.3	Comfortable posture: Desktop sitting	1.00	< **.001**
	Comfortable posture: Lying prone	0.91	< **.001**
	Comfortable posture: Lying supine	0.83	< **.001**
	Comfortable posture: Floor sitting	1.00	< **.001**
	Comfortable posture: Chair sitting	0.74	< **.001**
	Comfortable posture: Lap sitting	0.59	< **.001**
9.1	SHRRF: Type 10 pages	0.91	< **.001**
	SHRRF: Complete assignment on time	0.74	< **.001**
	SHRRF: Do assignment as well as you like	1.00	< **.001**
	SHRRF: Handwritten assignment	1.00	< **.001**
	SHRRF: Email with others	0.81	< **.001**
	SHRRF: Take notes in class by hand	1.00	< **.001**
	SHRRF: Take timed written examinations	1.00	< **.001**
	SHRRF: Use the moue	1.00	< **.001**
	SHRRF: Carry book around campus	0.71	< **.001**
	SHRRF: Sports activities	1.00	< **.001**
	SHRRF: Play musical instruments	1.00	< **.001**
	SHRRF: Play video games	0.78	< **.001**
	SHRRF: Use of mobile phones	1.00	< **.001**
	SHRRF: Lab activities	0.48	**.03**
	SHRRF: Intensive hand related activities	0.69	< **.001**
	SHRRF: Lifting or carrying groceries, box, books	1.00	< **.001**
10.1	Attitude Toward Laptop Computer: Easier	1.00	< **.001**
	Attitude Toward Laptop Computer: Enjoyable	0.65	< **.001**
	Attitude Toward Laptop Computer: Help me interact	0.80	< **.001**
	Attitude Toward Laptop Computer: Easier to take notes	0.80	< **.001**
	Attitude Toward Laptop Computer: Organize class notes	0.75	< **.001**
	Attitude Toward Laptop Computer: Distraction in class	0.37	**.01**
	Attitude Toward Laptop Computer: Rarely use	0.61	< **.001**
	Attitude Toward Laptop Computer: Do not enjoy	1.00	< **.001**
	Attitude Toward Laptop Computer: Frustrate me	0.41	**.03**

Table (Continued).

#	LCUSS items	Kappa	*p*
11.1	Recreational activities: Sports activities	0.90	< **.001**
	Recreational activities: Play a musical instruments	1.00	< **.001**
	Recreational activities: Play video games	1.00	< **.001**
	Recreational activities: Use mobile phone	.80	< **.001**
	Recreational activities: Laboratory activities	1.00	< **.001**
	Recreational activities: Intensive hand related activities	.49	< **.001**
	Recreational activities: Lifting or carrying groceries, boxes	1.00	< **.001**
12.6	Vision correction	1.00	< **.001**
12.7	Overall physical health	0.89	< **.001**
12.8	Comparison to the last year for the overall physical health	1.00	< **.001**

Note. SHRRF = Student Health Related Role Functioning; Bold indicates significant items

APPENDIX E

LAPTOP COMPUTER USER SCREENING SURVEY

Section 1	Demographic Information

1.1. **Date of Birth**___________________________

1.2. **Gender** (Check one)

(1)___________Male

(2)___________Female

1.3. **Height**____________ft. (and)_____________inches

1.4. **Weight**____________lbs.

1.5. **Ethnicity** (Check one)

(1)___________Hispanic or Latino (2)___________Non Hispanic or Latino

1.6. **Race** (Check all that apply)

(1)___________American Indian or Alaska Native

(2)___________Asian

(3)___________Black or African American

(4)___________Native Hawaiian or Other Pacific Islander

(5)___________White or Caucasian

(6)___________Other (Specify____)

1.7. **Dominant Hand** (Check one)

(1)___________Right

(2)___________Left

(3)___________Both

1.8. **Marital Status** (Check one)

(1)___________Never Married

(2)___________Married

(3)___________Divorced

(4)___________Widowed

(5)___________Separated

1.9. **What is your current enrollment status at the university?** (Check one)

(1)___________Full time student

(2)___________Part time student

1.10. **What year did you first enter the university?** ________________________year

1.11. **What year do you anticipate graduating?** ________________________year

1.12. **What is your class level?** (Check one)

(1)___________Freshman

(2)___________Sophomore

(3)___________Junior

(4)___________Senior

(5)___________Graduate or professional student (masters, doctoral, and post doctoral program)

(6)___________Special student (non-degree program)

(7)___________Other (Specify____)

1.13. **What is your residence classification at the university?** (Check one)

(1)___________In-state student

(2)___________Out-of-state student

(3)___________International student (not a U.S. citizen)

1.14. **Indicate your current university residence** (Check one)

(1)__________University residence hall

(2)__________Fraternity or sorority house

(3)__________University married student housing

(4)__________University graduate housing

(5)__________University-owned house or apartments

(6)__________Rented house or apartment

(7)__________Home of parents, guardians, or relatives

(8)__________Personally-owned home

(9)__________Other (Specify____)

Section 2	Location of Laptop Computer Use

2.1. **Where do you use your laptop computer? Please assign a percentage for each item. The total should equal 100%.**

(1)__________% Library

(2)__________% Campus classroom

(3)__________% Campus computer lab

(4)__________% Home

(5)__________% Café or restaurant

(6)__________% Outdoor places (yard, lawn, or street)

(7)__________% Transportation (in bus, car, or plane)

(8)__________% Other (Specify____)

100 % **Total**

2.2. **What is the reason for selection of location to use your laptop computer? Please rank the following reasons (1 = most important, 6 = least important, 0 = does not apply).**

(1) ___________Accessibility of wireless internet

(2) ___________Presence of electrical outlet

(3) ___________Presence of chair and desk

(4) ___________Presence of comfortable chair

(5) ___________Location is convenient

(6) ___________Other (Specify____)

Section 3	Laptop Transportation Methods

3.1. **How do you carry your laptop computer? Please check all that apply.**

(1) ___________Bag or briefcase with handle

(2) ___________Over the shoulder bag or briefcase

(3) ___________Rolling bag or briefcase

(4) ___________In your backpack

(5) ___________Other (Specify____)

3.2. **What devices do you typically <u>take</u> when carrying your laptop? Please check all that apply.**

(1) ___________External mouse (full or small size mice)

(2) ___________AC adapter

(3) ___________External battery

(4) ___________External keyboard

(5) ___________External disk drive

(6) ___________Extension cord

(7) ___________Other (Specify____)

3.3. **How severe is the discomfort (aching, cramping, sore, uncomfortable, stiff, dull, pressure, burning, or shooting) you experience with the following laptop transportation methods?**
Please mark an <u>"X"</u> on each line, which most closely describes your discomfort.
If not applicable, please check "N/A"

(1) Bag or briefcase with handle	**N/A** ☐	**No Discomfort**	**Unbearable Discomfort**
(2) Over the shoulder bag or briefcase	**N/A** ☐	**No Discomfort**	**Unbearable Discomfort**
(3) Rolling bag or briefcase	**N/A** ☐	**No Discomfort**	**Unbearable Discomfort**
(4) In your backpack	**N/A** ☐	**No Discomfort**	**Unbearable Discomfort**
(5) Other (If other method specified in #3.1)	**N/A** ☐	**No Discomfort**	**Unbearable Discomfort**

Section 4 | Laptop Related Tasks

4.1. **What types of tasks do you do most often when using your laptop?**
Please rank your top 3 activities (1 = most frequent, 3 = least frequent).

(1) ___________Word processing (word-related tasks)

(2) ___________Presentations (Power Point slide creation)

(3) ___________Analysis or spreadsheets (Excel, Lotus, Quattro Pro, etc.)

(4) ___________CourseWeb or online courses

(5) ___________Library search

(6) ___________Web surfing to collect work related resources (assignment or research)

(7) ___________Scheduling (schedule using the calendar)

(8) ___________Look up contacts (addresses or phone numbers)

(9) ___________Communication with others (internet chat, MSN, chat room, etc.)

(10) ___________Shopping

(11) ___________Check news, weather, sports, etc.

(12) ___________Check e-mail

(13)___________Watch movies or videos

(14)___________Pay bills

(15)___________Play games

(16)___________Other (Specify____)

Section 5	Laptop Specifications

5.1. **What model of laptop computer do you __typically__ use? Please check one.**

(1) ___________Apple Mac

(2)___________Sony

(3) ___________Lenovo (IBM)

(4)___________Gateway

(5) ___________Dell

(6)___________Toshiba

(7) ___________HP

(8)___________Compaq

(9) ___________Samsung

(10)___________Other (Specify____)

5.2. **What type of __input devices__ do you use with your laptop computer? Please check all that apply.**

(1)___________Mouse

(2)___________Trackball

(3)___________Joystick

(4)___________Touch pad

(5)___________Track point

(6)___________Keyboard

(7)___________Numeric keypad

(8)___________Other (Specify____)

5.3. **What type of __other devices__ do you use with your laptop computer? Please check all that apply.**

(1)___________Webcam

(2)___________Speakers

(3)___________Microphones

(4)___________Other (Specify____)

5.4. **How much does your laptop weigh, including battery? Please check one.**

(1)__________Less than 2.5 Ibs. (Netbook or subnotebook)

(2)__________2.6 – 4.9 Ibs. (Ultraportable)

(3)__________5 – 6.9 Ibs. (Thin and light)

(4)__________7 Ibs. or more (Desktop replacement)

5.5. **What is your laptop monitor size? (Monitor size is measured diagonally in inches) Please check one.**

(1)__________Less than 12 inches

(2)__________12 – 12.9 inches

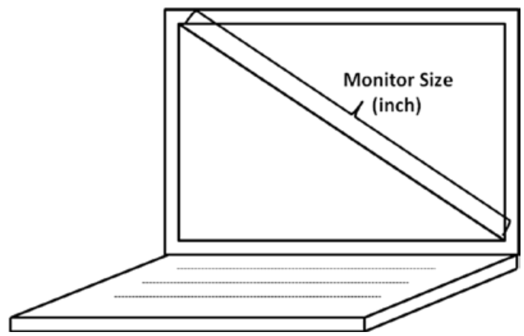
(3)__________13 – 13.9 inches

(4)__________14 – 14.9 inches

(5)__________15 – 15.9 inches

(6)__________16 – 16.9 inches

(7)__________17 inches or more



Section 6	Usage Time

6.1. **What percentage of <u>computing time</u> during a week do you spend working on a laptop and a desktop computer? Please assign a percentage for each item. The total should equal 100%.**

(1)__________% Laptop computer

(2)__________% Desktop computer

100 % **Total**

6.2. **On average, how many years have you used <u>any</u> laptop computer?** ____________years

6.3. **On average, how many hours per day do you use <u>any</u> laptop computer?**

________________hours ________________minutes

6.4. **On average, how long do you work on your laptop computer <u>without</u> rest breaks?**

_________________hours _________________minutes

6.5. **On average, how many minutes is a typical rest break during laptop computing? Please check one.**

(1)___________None

(2)___________< 5 min

(3)___________5 – 10 min

(4)___________11 – 15 min

(5)___________16 – 20 min

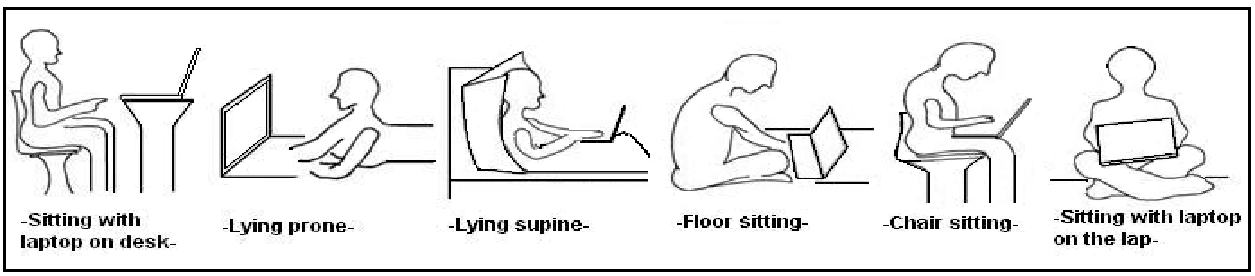
(6)___________21 – 25 min

(7)___________26 – 30 min

(8)___________> 30 min

Section 7	Laptop Workstation Setup

7.1. **What are your TYPICAL workstation setups during laptop computing? Please see following figures. The percentages should total 100%.**



(1)___________% Sitting with laptop on desk

(2)___________% Lying prone

(3)___________% Lying supine

(4)___________% Floor sitting

(5)___________% Chair sitting

(6)___________% Sitting with laptop on the lap

(7)___________% Other (Specify____)

100 % **Total**

7.2. **How severe is the discomfort (aching, cramping, sore, uncomfortable, stiff, dull, pressure, burning, or shooting) you experience with the following laptop workstation setups?**
Please mark an "<u>X</u>" on each line. If not applicable, please check "N/A"

(1) Sitting with laptop on desk	**N/A** ☐	**No Discomfort**	**Unbearable Discomfort**
(2) Lying prone	**N/A** ☐	**No Discomfort**	**Unbearable Discomfort**
(3) Lying supine	**N/A** ☐	**No Discomfort**	**Unbearable Discomfort**
(4) Floor sitting	**N/A** ☐	**No Discomfort**	**Unbearable Discomfort**
(5) Chair sitting	**N/A** ☐	**No Discomfort**	**Unbearable Discomfort**
(6) Sitting with laptop on the lap	**N/A** ☐	**No Discomfort**	**Unbearable Discomfort**
(7) Other (If other posture specified in #7.1)	**N/A** ☐	**No Discomfort**	**Unbearable Discomfort**

7.3. **What is your most COMFORTABLE workstation setup during laptop computing? Please rank the following postures (1 = most comfortable, 6 = least comfortable, 0 = does not apply).**

(1)__________Sitting with laptop on desk

(2)__________Lying prone

(3)__________Lying supine

(4)__________Floor sitting

(5)__________Chair sitting

(6)__________Sitting with laptop on the lap

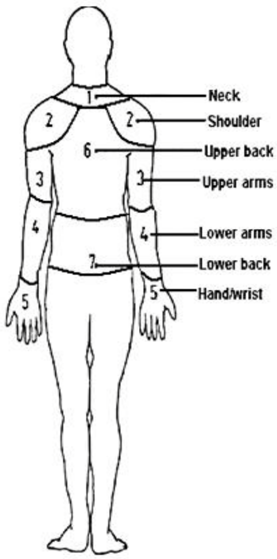
(7)__________Other (Specify____)

Section 8 Overall Laptop Related Discomfort

8.1. **Have you ever experienced discomfort in your neck, shoulders, arms, hands, wrists, upper back, and trunk, during laptop computing?**

(1)__________No (Please go to Section 9) (2)__________Yes (Please answer 8.2)

8.2. **How severe is the discomfort you <u>usually</u> experience when working on a laptop computer? Please mark an <u>"X"</u> on each line, which most closely describes your discomfort for each body region.**



Number on Chart	Body Region	No Discomfort ⟷ Unbearable Discomfort
1	(1) Neck	
Rt. 2	(2) Rt. Shoulder	
Lt. 2	(3) Lt. Shoulder	
Rt. 3	(4) Rt. Upper Arm	
Lt. 3	(5) Lt. Upper Arm	
Rt. 4	(6) Rt. Lower Arm	
Lt. 4	(7) Lt. Lower Arm	
Rt. 5	(8) Rt. Hand/Wrist	
Lt. 5	(9) Lt. Hand/Wrist	
6	(10) Upper Back	
7	(11) Lower Back	

Section 9 Student Health Related Role Functioning

9.1. **In tl ast <u>2 weeks</u>, how much difficulty have you had with the following activities as a result of discomfort in your hands, wrists, arms, shoulders, back, or neck? Please circle <u>one response</u> for each line.**

	No difficulty	Mild difficulty	Moderate difficulty	Severe difficulty	So difficult I cannot do at all	N/A
(1) Type 10 pages (double spaced) on the laptop computer	0	1	2	3	4	N/A
(2) Complete assignments on the laptop computer (such as typed papers) on time	0	1	2	3	4	N/A
(3) Do assignments on the laptop computer as well as you would like	0	1	2	3	4	N/A
(4) Complete handwritten assignments (such as problem sets)	0	1	2	3	4	N/A
(5) Correspond as often as you would like by email with friends, faculty and others	0	1	2	3	4	N/A
(6) Take notes in class by hand	0	1	2	3	4	N/A
(7) Take timed written examinations	0	1	2	3	4	N/A
(8) Use the mouse (or other laptop computer pointing devices) repeatedly	0	1	2	3	4	N/A
(9) Carry your books around campus	0	1	2	3	4	N/A
(10) Sports activities, such as running, lifting weights, participating in sports	0	1	2	3	4	N/A
(11) Play a musical instrument (piano, guitar, violin, etc.)	0	1	2	3	4	N/A
(12) Play video games	0	1	2	3	4	N/A
(13) Use of mobile phones for phoning, playing games, or text messages	0	1	2	3	4	N/A
(14) Laboratory activities such as using a pipette or soldering iron	0	1	2	3	4	N/A
(15) Intensive hand related activities (handwriting, sorting books, journals, etc.)	0	1	2	3	4	N/A
(16) Lifting or carrying groceries, boxes, or books	0	1	2	3	4	N/A

Section 10	Attitude Toward the Laptop Computer

10.1. **In this section, we are interested in your general attitude toward the laptop computer. How much do you agree or disagree with the following statements? Please check <u>one response</u> for each question.**

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
(1) A laptop computer makes university easier					
(2) A laptop computer makes university more enjoyable					
(3) A laptop computer helps me interact with other students					
(4) It is easier for me to take notes during class with my laptop					
(5) I can organize my class notes easily with my laptop					
(6) A laptop is a distraction in class					
(7) I rarely use my laptop					
(8) I do not enjoy using my laptop					
(9) I am often frustrated with my laptop					

Section 11	Recreational Activities

11.1. **During an average week, how many hours do you spend on the following activities? Please check <u>one response</u> for each question.**

	Never or Rarely	Up to 5 hours	6 to 10 hours	11 to 20 hours	More than 20 hours
(1) Sports activities, such as running, lifting weights, participating in sports					
(2) Play a musical instrument (piano, guitar, violin, flute, etc.)					
(3) Play video games					
(4) Use a mobile phone for phoning, playing games, or text messages					
(5) Laboratory activities such as using a pipette or soldering iron					
(6) Intensive hand related activities (handwriting, sorting books, journals, etc.)					
(7) Lifting or carrying groceries, boxes, or books					

Section 12	Previous/Current Health Status

12.1. **Have you ever been diagnosed or treated by a doctor for pain/discomfort in your neck, shoulders, arms, hands, wrists, or trunk?**

(1)__________No (Please go to 12.3) (2)__________Yes (Please answer 12.2)

12.2. **What type of diagnosis did you receive from a doctor? Please check all that apply.**

(1)________Muscle spasm or sprain (2) ________Tendonitis

(3)________Ruptured or herniated disk in back (4) ________Thoracic outlet syndrome

(5)________Ruptured or herniated disk in neck (6) ________Ligament strain

(7)________Lower back pain (8) ________Tennis elbow

(9)________Pinched nerve (10)________Tenosynovitis

(11)_______Carpal tunnel syndrome (12)________Bursitis

(13)_______Other (Specify____)

12.3 **Do you smoke cigarettes?**

(1)__________No (Please go to 12.5) (2)__________Yes (Please answer 12.4)

12.4. **On average, how many cigarettes do you smoke each day? Please check one.**

(1)__________1 cigarette (2)__________2 – 5 cigarettes

(3)__________6 – 10 cigarettes (4)__________11 –15 cigarettes

(5)__________16 – 20 cigarettes (6)__________between one and two packs

(7)__________More than two packs

12.5. **Do you use other forms of tobacco, other than cigarettes?**

(1)__________No (2)__________I smoke a pipe

(3)__________I use snuff (4)__________I chew tobacco

12.6. **Is your vision corrected?**

(1)___________Uncorrected vision

(2)___________Corrected with contact lenses

(3)___________Corrected with glasses

(4)___________Corrected with surgery

12.7. **In general, how would you describe your overall physical health?**

(1)___________Excellent

(2)___________Good

(3)___________Fair

(4)___________Poor

12.8. **Compared to one year ago, how would you rate your overall physical health?**

(1)___________Much better now than one year ago

(2)___________Somewhat better now than one year ago

(3)___________About the same as one year ago

(4)___________Somewhat worse now than one year ago

(5)___________Much worse now than one year ago

APPENDIX F

FLYER FOR AN OBSERVATIONAL STUDY

PARTICIPANTS NEEDED

For an Observational Study of Laptop Work Postures

Purpose:

- We will examine how different laptop work postures affect discomfort and body angles.

Procedure:

- You will be asked to complete a survey questionnaire.
- You will perform a 10 min keyboard text-entry tasks in six simulated laptop work postures (e.g., sitting with laptop on desk, lying prone, lying supine, floor sitting, chair sitting, and sitting with laptop on the lap) with 5 min break in between each posture.
- This evaluation will take about 3 hours.

Requirements:

- Undergraduate or graduate students from the University of Pittsburgh
- 18 years of age or older
- Use of a laptop computer
- No injuries or illness, such as fracture or carpal tunnel syndrome, which can interrupt text-entry tasks
- No current injuries in the back, neck, shoulder, and upper limbs
- Ability to tolerate the laptop tasks for 3 hours

Payment:

Each person who completes this research study will be entered into a raffle to receive one of five $20 Starbucks gift cards.

For more information, please contact Hyekyoung
Phone: 412–337–4856, Email: hys6@pitt.edu

Laptop Study 412-337-4856 hys6@pitt.edu	Laptop Study 412-337-4856 hys6@pitt.edu	Laptop Study 412-337-4856 hys6@pitt.edu	Laptop Study 412-337-4856 hys6@pitt.edu	Laptop Study 412-337-4856 hys6@pitt.edu	Laptop Study 412-337-4856 hys6@pitt.edu	Laptop Study 412-337-4856 hys6@pitt.edu	Laptop Study 412-337-4856 hys6@pitt.edu	Laptop Study 412-337-4856 hys6@pitt.edu	Laptop Study 412-337-4856 hys6@pitt.edu	Laptop Study 412-337-4856 hys6@pitt.edu	Laptop Study 412-337-4856 hys6@pitt.edu

APPENDIX G

RESEARCH INVITATION LETTER

University of Pittsburgh

School of Health and Rehabilitation Sciences
Department of Occupational Therapy

Dear Friends,

You are invited to join the LAPTOP RESEARCH STUDY at the University of Pittsburgh. This study is to examine how different laptop work postures (e.g., sitting with laptop on desk, lying prone, lying supine, floor sitting, chair sitting, and sitting with laptop on the lap) affect body angles and discomfort. We are inviting you to join this laptop study. With rapid increase in the use of laptop computers, concerns about musculoskeletal disorders among laptop computer users have been increasing. This study will provide laptop users with information about how to relate laptop work postures to potential musculoskeletal disorders and, thus, will provide guidelines.

You are eligible for this study if you are:
1. Undergraduate and graduate students from the University of Pittsburgh
2. 18 years of age or older
3. Use of a laptop computer
3. No injuries or illness, such as fracture or carpal tunnel syndrome, which can interrupt text-entry tasks
4. Ability to tolerate the laptop tasks for 2 ½ hours

If you decide to be in this research study, you will be asked questions about how you use your laptop. You will perform 10 min keyboard text-entry tasks in six simulated laptop work posture with 5 min break in between. While keyboarding a laptop computer, your postures will be video-recorded, so we can look at it later. There are no invasive procedures or medications in this study. To thank you for your contribution to this research study, your name will be entered into an end-of-study raffle drawing to receive one of five $20 Starbucks gift cards.

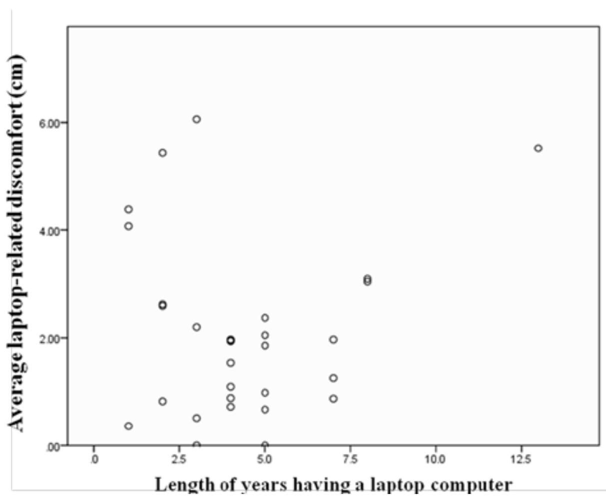
Please feel free to contact us for more information or to discuss your eligibility for this study.
Phone: 412-337-4856, Email: hys6@pitt.edu

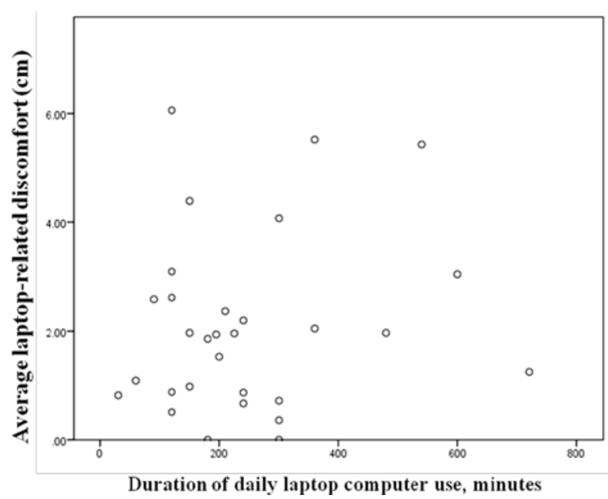
Sincerely,

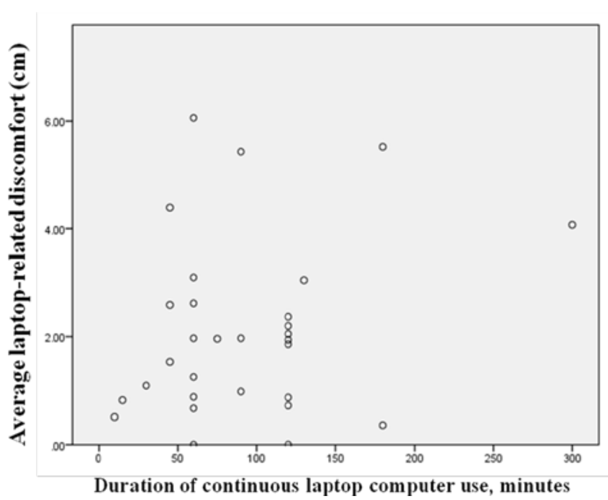
Hyekyoung Shin
Department of Occupational Therapy
University of Pittsburgh
5021 Forbes Tower
Pittsburgh, PA 15260
Phone: 412-383-6767
Email: hys6@pitt.edu

APPENDIX H

SCATTER PLOT OF LINEAR RELATIONSHIP BETWEEN DURATION OF LAPTOP USE AND AVERAGE LAPTOP-RELATED DISCOMFORT

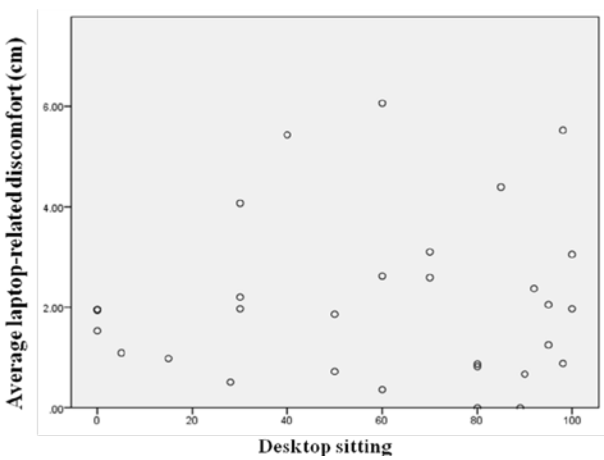


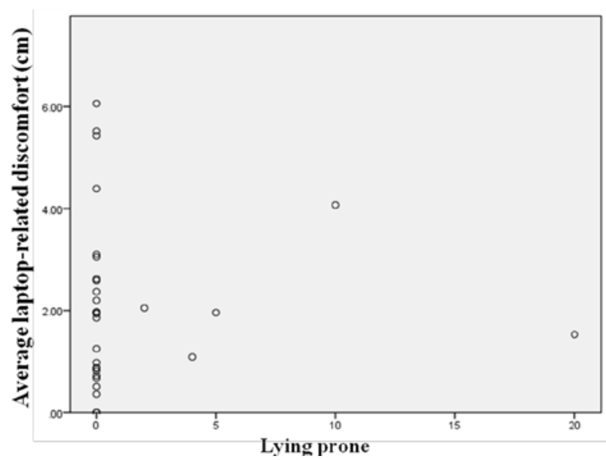


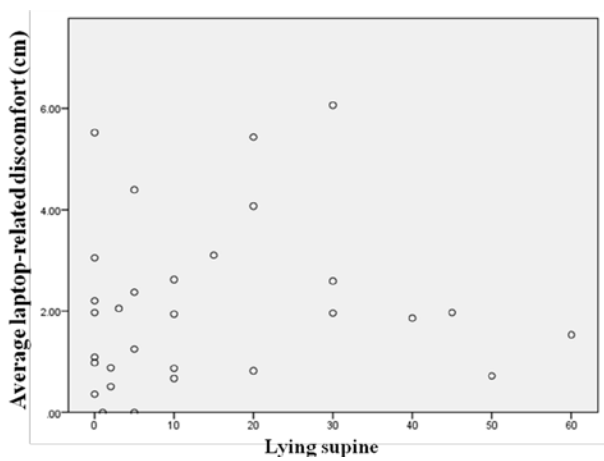


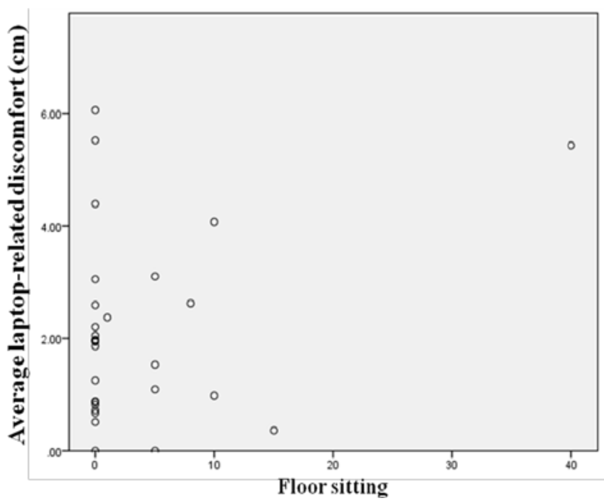
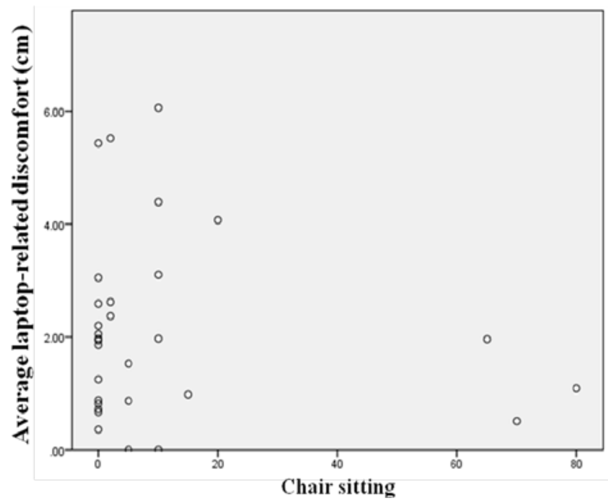
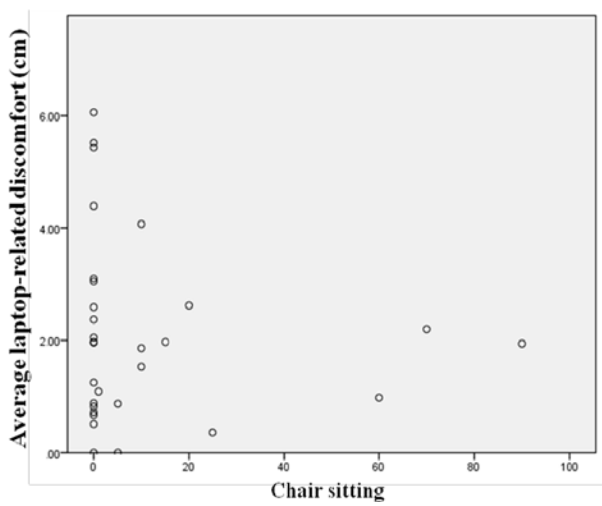
APPENDIX I

SCATTER PLOT OF LINEAR RELATIONSHIP BETWEEN PERCENTAGE OF TIME SPENT IN A LAPTOP WORKSTATION SETUP AND AVERAGE LAPTOP-RELATED DISCOMFORT



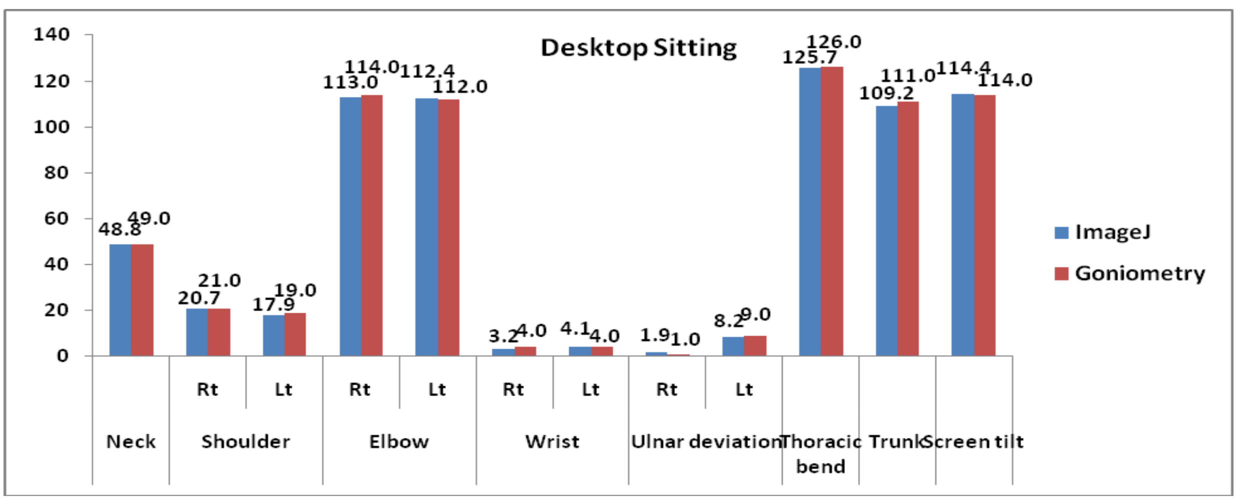


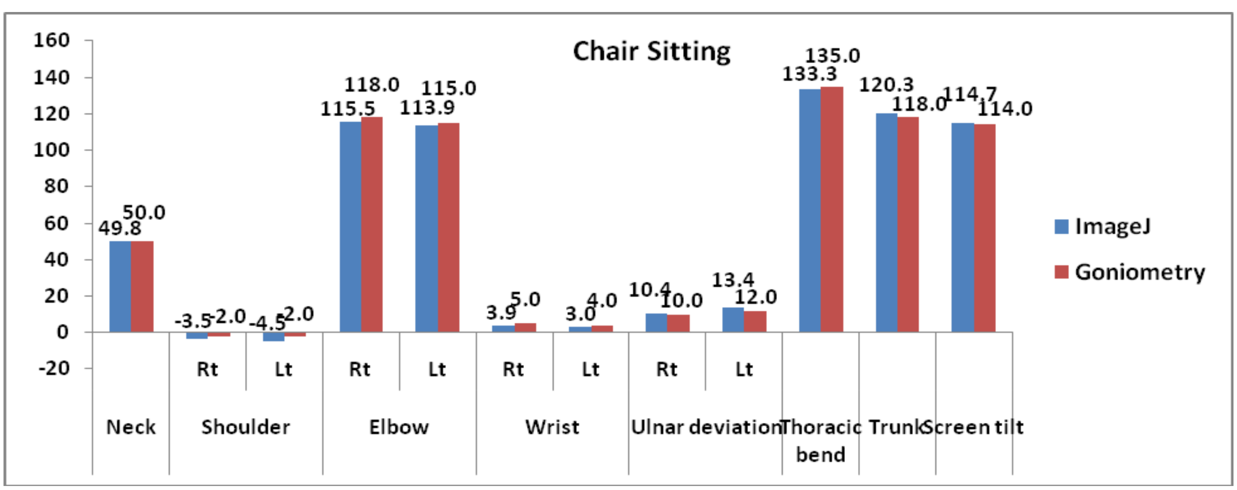


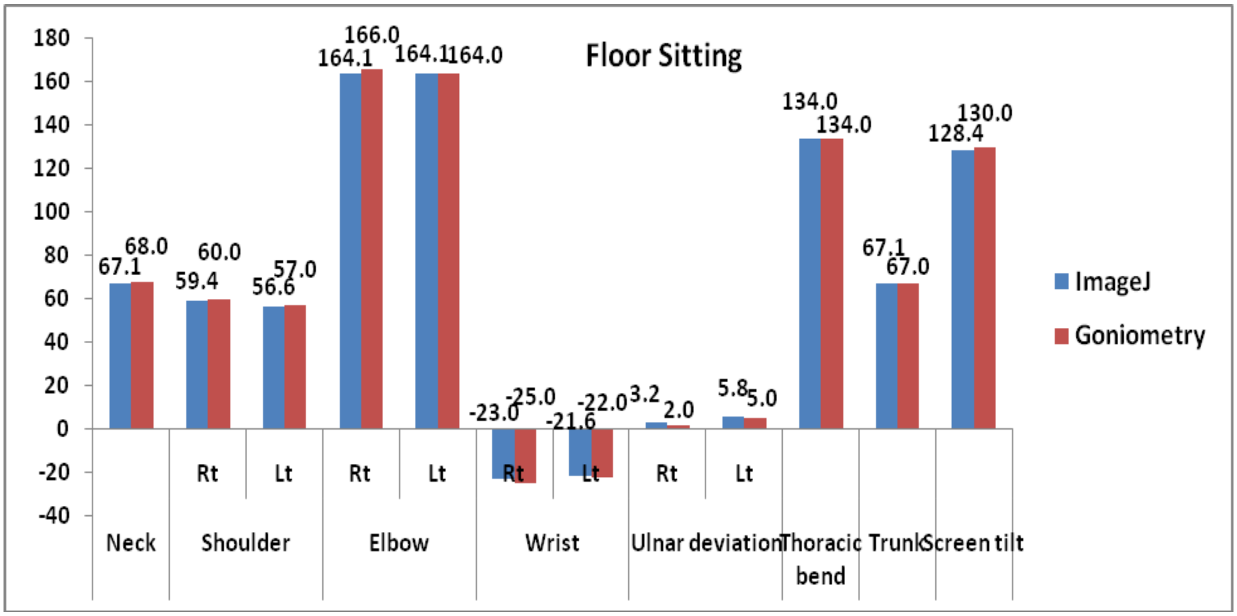

Average laptop-related discomfort (cm)
Floor sitting

Average laptop-related discomfort (cm)
Chair sitting

Average laptop-related discomfort (cm)
Chair sitting

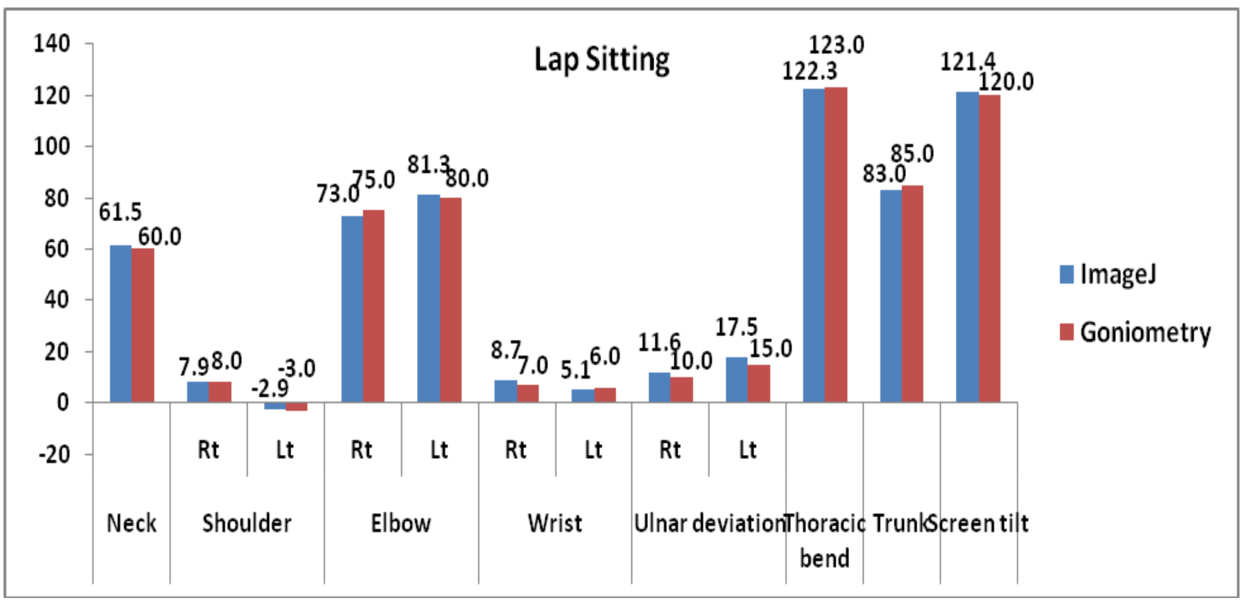
APPENDIX J

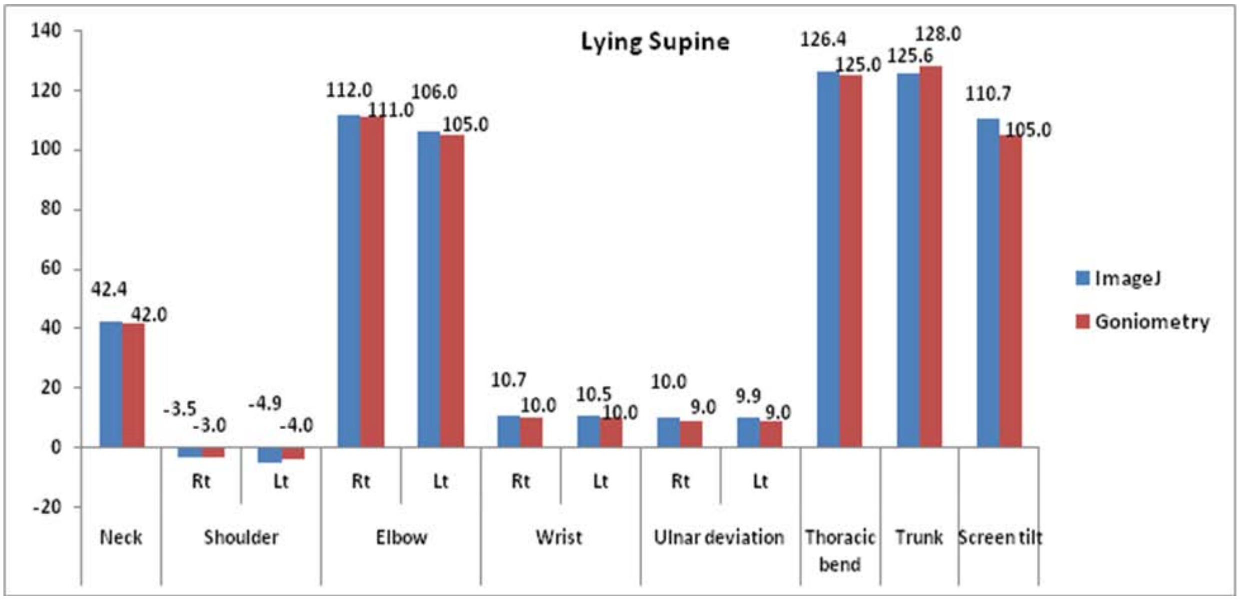
MEASURED ANGLES IN SIX SIMULATED LAPTOP WORKSTATION SETUPS BETWEEN IMAGEJ AND GONIOMETER

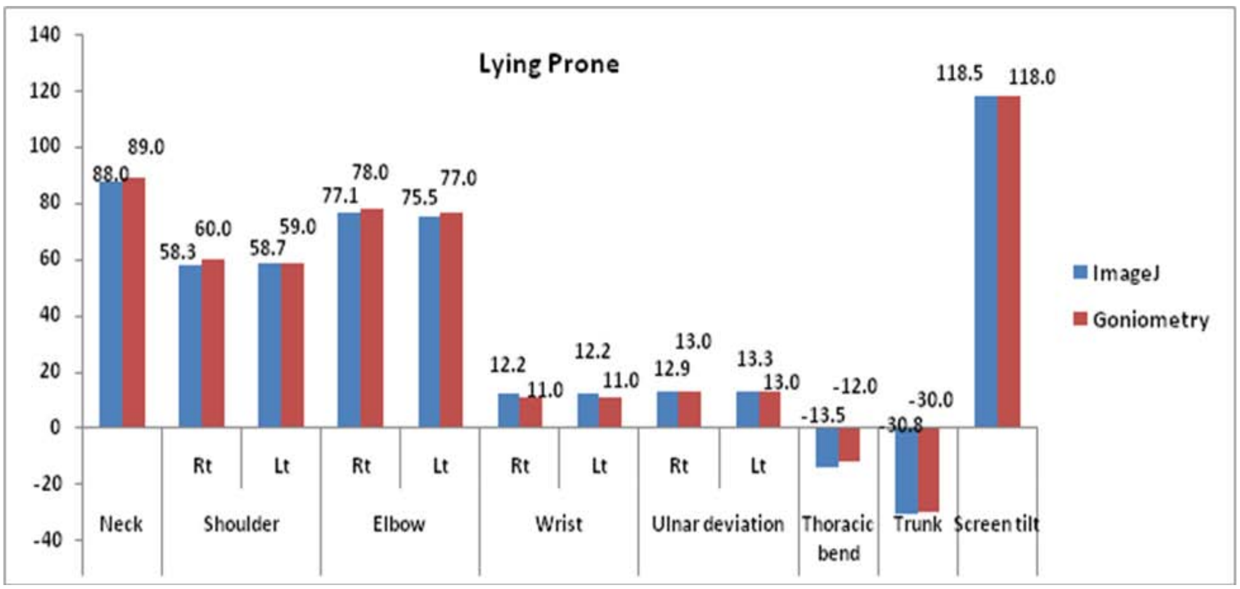





Floor Sitting
180
160
140
120
100
80
60
40
20
0
-20
-40
67.1
68.0
59.4
60.0
56.6
57.0
164.1
166.0
164.1
164.0
-23.0
-25.0
-21.6
-22.0
3.2
2.0
5.8
5.0
134.0
134.0
67.1
67.0
128.4
130.0
Rt
Lt
Rt
Lt
Rt
Lt
Rt
Lt
Neck
Shoulder
Elbow
Wrist
Ulnar deviation
Thoracic bend
Trunk
Screen tilt
ImageJ
Goniometry


Lap Sitting
140
120
100
80
60
40
20
0
-20
61.5
60.0
7.9
8.0
-2.9
-3.0
73.0
75.0
81.3
80.0
8.7
7.0
5.1
6.0
11.6
10.0
17.5
15.0
122.3
123.0
83.0
85.0
121.4
120.0
Rt
Lt
Rt
Lt
Rt
Lt
Rt
Lt
Neck
Shoulder
Elbow
Wrist
Ulnar deviation
Thoracic bend
Trunk
Screen tilt
ImageJ
Goniometry


Lying Supine
ImageJ
Goniometry
140
120
100
80
60
40
20
0
-20
42.4
42.0
-3.5
-3.0
-4.9
-4.0
112.0
111.0
106.0
105.0
10.7
10.0
10.5
10.0
10.0
9.0
9.9
9.0
126.4
125.0
125.6
128.0
110.7
105.0
Rt
Lt
Rt
Lt
Rt
Lt
Rt
Lt
Neck
Shoulder
Elbow
Wrist
Ulnar deviation
Thoracic bend
Trunk
Screen tilt


Lying Prone
ImageJ
Goniometry
140
120
100
80
60
40
20
0
-20
-40
88.0
89.0
58.3
60.0
58.7
59.0
77.1
78.0
75.5
77.0
12.2
11.0
12.2
11.0
12.9
13.0
13.3
13.0
-13.5
-12.0
-30.8
-30.0
118.5
118.0
Rt
Lt
Rt
Lt
Rt
Lt
Rt
Lt
Neck
Shoulder
Elbow
Wrist
Ulnar deviation
Thoracic bend
Trunk
Screen tilt

APPENDIX K

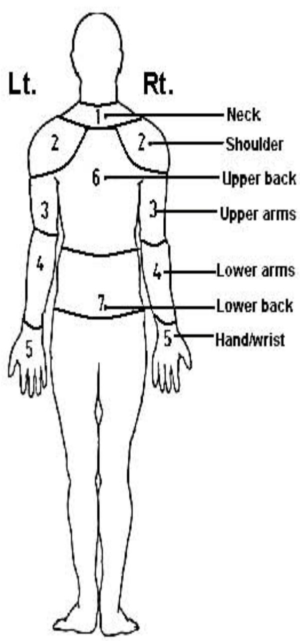
DISCOMFORT RATING CHART

ID CODE____________________ **DATE:** _______/_______/_______

Discomfort Rating Chart

Type of Laptop Workstation:___________________________________

How severe discomfort did you experience while working on a laptop computer?
Please mark an "X" on each line, which most closely describes your discomfort for each body region.



Number on Chart	Body Region	No Discomfort ⟷ Unbearable Discomfort
1	(1) Neck	______________
Rt. 2	(2) Rt. Shoulder	______________
Lt. 2	(3) Lt. Shoulder	______________
Rt. 3	(4) Rt. Upper Arm	______________
Lt. 3	(5) Lt. Upper Arm	______________
Rt. 4	(6) Rt. Lower Arm	______________
Lt. 4	(7) Lt. Lower Arm	______________
Rt. 5	(8) Rt. Hand/Wrist	______________
Lt. 5	(9) Lt. Hand/Wrist	______________
6	(10) Upper Back	______________
7	(11) Lower Back	______________

APPENDIX L

POST-HOC ANALYSIS OF ANGLES BETWEEN THE THREE LAPTOP WORKSTATION SETUPS

Postural angle (deg)	Post-hoc analysis	Mean difference	p^{c}
Neck angle	Desktop sitting vs. Lying supine	10.8	**< .001**
	Desktop sitting vs. Chair sitting	-9.5	**< .001**
	Lying supine vs. Chair sitting	-20.3	**< .001**
Rt. shoulder angle$^{\alpha}$	Desktop sitting vs. Lying supine	25.7	**< .001**
	Desktop sitting vs. Chair sitting	21.7	**.02**
	Lying supine vs. Chair sitting	-4.0	**< .001**
Lt. shoulder angle$^{\alpha}$	Desktop sitting vs. Lying supine	27.0	**< .001**
	Desktop sitting vs. Chair sitting	21.9	**< .001**
	Lying supine vs. Chair sitting	-5.2	**< .001**
Rt. wrist angle$^{\alpha}$	Desktop sitting vs. Lying supine	-5.1	**.03**
	Desktop sitting vs. Chair sitting	2.9	.17
	Lying supine vs. Chair sitting	7.9	**< .001**
Lt. wrist angle$^{\alpha}$	Desktop sitting vs. Lying supine	-7.8	**< .001**
	Desktop sitting vs. Chair sitting	4.1	.07
	Lying supine vs. Chair sitting	11.9	**< .001**

Table (Continued).

Postural angle (deg)	Post-hoc analysis	Mean difference	p^c
Rt. ulnar/radial deviation[b]	Desktop sitting vs. Lying supine	-5.1	**< .001**
	Desktop sitting vs. Chair sitting	-7.1	**< .001**
	Lying supine vs. Chair sitting	-2.0	**.01**
Lt. ulnar/radial deviation[b]	Desktop sitting vs. Lying supine	-4.8	**< .001**
	Desktop sitting vs. Chair sitting	-6.2	**< .001**
	Lying supine vs. Chair sitting	-1.5	.05
Thoracic bend angle[α]	Desktop sitting vs. Lying supine	17.8	**< .001**
	Desktop sitting vs. Chair sitting	8.9	**< .001**
	Lying supine vs. Chair sitting	-9.0	**< .001**
Trunk angle[α]	Desktop sitting vs. Lying supine	-33.9	**< .001**
	Desktop sitting vs. Chair sitting	-9.5	**< .001**
	Lying supine vs. Chair sitting	24.4	**< .001**
View angle	Desktop sitting vs. Lying supine	6.8	**.02**
	Desktop sitting vs. Chair sitting	-17.7	**< .001**
	Lying supine vs. Chair sitting	-24.6	**< .001**

Note. Rt. = Right; Lt. = Left; [a]The plus sign (+) indicates flexion and the minus sign (–) indicates extension; [b]The plus sign (+) indicates ulnar deviation of the wrist and the minus sign (–) indicates radial deviation of the wrist; [c]Statistical significance was set at $p < .05$; Bold indicates significant items

APPENDIX M

COMPARISON OF K-PECS AND ANOVA SUMMARY BETWEEN THREE LAPTOP WORKSTATION SETUPS

K-PeCS items	Mean rank			χ^2	*df*	*p*[a]
	Desktop sitting	Lying supine	Chair sitting			
Torso angle	2.7	1.3	2.1	42.20	2	< **.001**
Back rest use	2.5	1.5	2.0	28.53	2	< **.001**
Head flexion angle	1.3	2.5	2.3	41.61	2	< **.001**
Rt. shoulder flexion angle	2.7	1.6	1.7	42.09	2	< **.001**
Lt. shoulder flexion angle	2.7	1.6	1.6	44.00	2	< **.001**
Rt. elbow flexion angle	2.0	2.1	1.9	1.86	2	.40
Lt. elbow flexion angle	2.0	2.0	2.0	0.11	2	.95
Forearm support use	1.7	2.1	2.3	10.66	2	< **.001**
Rt. wrist support use	2.1	1.8	2.1	6.23	2	**.04**
Lt. wrist support use	2.1	1.9	2.1	3.90	2	.14
Rt. wrist/hand movement	1.9	2.1	2.0	4.33	2	.12
Lt. wrist/hand movement	1.9	2.1	2.0	4.31	2	.12
Force	2.1	1.9	2.0	1.75	2	.42

Table (Continued).

K-PeCS items	Mean rank			χ^2	*df*	*p*[a]
	Desktop sitting	Lying supine	Chair sitting			
Rt. ulnar angle > 20°	1.6	2.2	2.3	17.03	2	< **.001**
Lt. ulnar angle > 20°	1.5	2.3	2.2	19.97	2	< **.001**
Rt. wrist extension > 15°	1.7	1.7	2.6	18.27	2	< **.001**
Lt. wrist extension > 15°	1.9	1.8	2.4	8.91	2	**.01**
Rt. changes in pronation	1.9	2.1	2.1	4.50	2	.11
Lt. changes in pronation	2.0	2.0	2.0	2.00	2	.37
Rt. isolated 5th digit	1.9	2.3	1.9	10.67	2	< **.001**
Lt. isolated 5th digit	1.8	2.1	2.1	5.21	2	.07
Rt. isolated thumb	2.0	2.0	2.0	2.00	2	.37
Lt. isolated thumb	1.9	2.1	2.1	3.00	2	.22
Space bar activation	2.0	2.0	2.0	0.00	2	1.00
Rt. # of digits used to type	2.0	2.0	2.0	0.00	2	1.00
Lt. # of digits used to type	2.0	2.0	2.0	0.00	2	1.00
R-3 MCP hyperextension	2.0	2.1	2.0	1.63	2	.44
R-4 MCP hyperextension	1.9	2.0	2.2	3.50	2	.17
R-5 MCP hyperextension	1.9	2.1	2.0	2.04	2	.36
L-3 MCP hyperextension	1.9	2.2	1.9	10.75	2	< **.001**
L-4 MCP hyperextension	1.6	2.2	2.2	11.56	2	< **.001**
L-5 MCP hyperextension	1.5	2.3	2.2	22.46	2	< **.001**

Table (Continued).

K-PeCS items	Mean rank			χ^2	*df*	*p*[a]
	Desktop sitting	Lying supine	Chair sitting			
R-3 PIP/DIP curve	2.0	2.0	2.0	2.00	2	.37
R-4 PIP/DIP curve	2.0	2.0	2.0	2.00	2	.37
R-5 PIP/DIP curve	2.0	2.0	2.0	0.00	2	1.00
L-3 PIP/DIP curve	2.0	2.0	2.0	0.00	2	1.00
L-4 PIP/DIP curve	2.0	2.0	2.0	0.00	2	1.00
L-5 PIP/DIP curve	2.0	2.1	2.0	3.00	2	.22
Rt. hypermobility	2.0	2.0	2.0	0.00	2	1.00
Rt. hypermobility	2.0	2.0	2.0	2.00	2	.37

Note. Rt. = Right; Lt. = Left; MCP = Metacarpophalangeal joints; PIP = Proximal interphalangeal joints; DIP = Distal interphalangeal joints; [a]Statistical significance was set at $p < .05$; Bold indicates significant items

APPENDIX N

POST-HOC ANALYSIS OF K-PECS BETWEEN THREE LAPTOP WORKSTATION SETUPS

K-PeCS Items	Post-Hoc Analysis	Z	*P*[d]
Torso angle	Desktop sitting vs. Lying supine	-4.70[a]	< **.001**
	Desktop sitting vs. Chair sitting	-3.53[a]	< **.001**
	Lying supine vs. Chair sitting	-4.00[b]	< **.001**
Back rest use	Desktop sitting vs. Lying supine	-4.36[a]	< **.001**
	Desktop sitting vs. Chair sitting	-3.16[a]	< **.001**
	Lying supine vs. Chair sitting	-3.00[b]	< **.001**
Head flexion angle	Desktop sitting vs. Lying supine	-4.18[a]	< **.001**
	Desktop sitting vs. Chair sitting	-4.27[a]	< **.001**
	Lying supine vs. Chair sitting	-2.07[a]	< **.001**
Rt. shoulder flexion angle	Desktop sitting vs. Lying supine	-4.35[a]	< **.001**
	Desktop sitting vs. Chair sitting	-4.25[a]	< **.001**
	Lying supine vs. Chair sitting	-1.00[b]	.32
Lt. shoulder flexion angle	Desktop sitting vs. Lying supine	-4.28[a]	< **.001**
	Desktop sitting vs. Chair sitting	-4.28[a]	< **.001**
	Lying supine vs. Chair sitting	0.00[b]	1.00

Table (Continued).

K-PeCS Items	Post-Hoc Analysis	Z	P^d
Forearm support use	Desktop sitting vs. Lying supine	-1.94[a]	.05
	Desktop sitting vs. Chair sitting	-3.17[a]	< **.001**
	Lying supine vs. Chair sitting	-0.74[a]	.46
Rt. wrist support use	Desktop sitting vs. Lying supine	-2.08[a]	.04
	Desktop sitting vs. Chair sitting	-0.30[b]	.76
	Lying supine vs. Chair sitting	-2.33[b]	.02
Rt. ulnar angle > 20°	Desktop sitting vs. Lying supine	-3.10[a]	< **.001**
	Desktop sitting vs. Chair sitting	-3.37[a]	< **.001**
	Lying supine vs. Chair sitting	-0.54[a]	.59
Lt. ulnar angle > 20°	Desktop sitting vs. Lying supine	-3.46[a]	< **.001**
	Desktop sitting vs. Chair sitting	-3.39[a]	< **.001**
	Lying supine vs. Chair sitting	-0.16[b]	.87
Rt. wrist extension > 15°	Desktop sitting vs. Lying supine	-0.75[a]	.45
	Desktop sitting vs. Chair sitting	-3.76[b]	< **.001**
	Lying supine vs. Chair sitting	-2.92[b]	< **.001**
Lt. wrist extension > 15°	Desktop sitting vs. Lying supine	-0.35[a]	.73
	Desktop sitting vs. Chair sitting	-2.86[b]	< **.001**
	Lying supine vs. Chair sitting	-2.35[b]	.02
Rt. isolated 5th digit	Desktop sitting vs. Lying supine	-2.71[a]	**.01**
	Desktop sitting vs. Chair sitting	0.00[b]	1.00
	Lying supine vs. Chair sitting	-2.71[c]	.01

Table (Continued).

K-PeCS Items	Post-Hoc Analysis	Z	*P*[d]
L-3 MCP hyperextension	Desktop sitting vs. Lying supine	-2.43[a]	**.015**
	Desktop sitting vs. Chair sitting	-0.58[a]	.56
	Lying supine vs. Chair sitting	-2.25[b]	.02
L-4 MCP hyperextension	Desktop sitting vs. Lying supine	-2.83[a]	**.01**
	Desktop sitting vs. Chair sitting	-2.83[a]	**.01**
	Lying supine vs. Chair sitting	0.00[b]	1.00
L-5 MCP hyperextension	Desktop sitting vs. Lying supine	-4.12[a]	< **.001**
	Desktop sitting vs. Chair sitting	-3.74[a]	< **.001**
	Lying supine vs. Chair sitting	-0.83[b]	.41

Note. Rt. = Right; Lt. = Left; MCP = Metacarpophalangeal joints; [a]based on the positive ranks; [b]based on negative ranks; [c]Wilcoxon signed ranks test; [d]Statistical significance was set at $p < .0167$; Bold indicates significant items

APPENDIX O

COMPARISON OF PHYSICAL DISCOMFORT AND ANOVA SUMMARY BETWEEN THREE LAPTOP WORKSTATION SETUPS

Body regions (cm)	Desktop sitting	Lying supine	Chair sitting	*F*	*p*[a]	$\eta_P{}^2$
Neck	2.2 ± 2.3	2.4 ± 2.2	3.1 ± 2.7	2.29	.11	.07
Rt. shoulder	1.1 ± 1.7	0.8 ± 1.1	1.8 ± 2.6	3.76	**.03**	.12
Lt. shoulder	1.2 ± 1.7	0.9 ± 1.4	1.8 ± 2.6	3.32	**.04**	.10
Rt. upper arm	0.7 ± 0.8	0.8 ± 1.1	1.1 ± 1.5	1.62	.21	.05
Lt. upper arm	0.8 ± 0.9	0.8 ± 1.1	1.2 ± 1.5	1.36	.26	.05
Rt. lower arm	0.7 ± 0.8	0.8 ± 0.9	1.1 ± 1.3	2.60	.09	.08
Lt. lower arm	0.7 ± 0.8	0.8 ± 0.9	1.1 ± 1.3	2.54	.10	.08
Rt. hand/wrist	0.9 ± 1.4	1.0 ± 1.2	1.2 ± 1.5	1.36	.26	.05
Lt. hand/wrist	0.9 ± 1.5	1.0 ± 1.3	1.4 ± 1.6	2.09	.15	.07
Upper back	1.6 ± 2.2	1.5 ± 1.8	2.4 ± 2.5	6.01	< **.001**	.17
Lower back	1.5 ± 1.9	1.4 ± 2.0	1.4 ± 1.6	0.06	.94	.00

Note. Rt. = Right; Lt. = Left; [a]Statistical significance was set at $p < .05$; Bold indicates significant items

APPENDIX P

POST-HOC ANALYSIS OF PHYSICAL DISCOMFORT BETWEEN THREE LAPTOP WORKSTATION SETUPS

Body regions (cm)	Post-hoc analysis	Mean difference	p^a
Rt. shoulder	Desktop sitting vs. Lying supine	0.2	1.00
	Desktop sitting vs. Chair sitting	-0.7	.12
	Lying supine vs. Chair sitting	-1.0	.09
Lt. shoulder	Desktop sitting vs. Lying supine	0.3	1.00
	Desktop sitting vs. Chair sitting	-0.7	.20
	Lying supine vs. Chair sitting	-1.0	.10
Upper back	Desktop sitting vs. Lying supine	0.1	1.00
	Desktop sitting vs. Chair sitting	-0.8	**.01**
	Lying supine vs. Chair sitting	-0.9	**.02**

Note. Rt. = Right; Lt. = Left; [a]Statistical significance was set at $p < .05$; Bold indicates significant items

APPENDIX Q

COMPARISON OF TASK PRODUCTIVITY AND ANOVA SUMMARY BETWEEN THREE LAPTOP WORKSTATION SETUPS

Productivity	Mean ± SD			*F*	*p*[d]	η_P^2
	Desktop sitting	Lying supine	Chair sitting			
Net speed[a]	46.5 ± 15.8	44.3 ± 15.7	39.6 ± 14.1	41.28	< **.001**	.59
Gross speed[a]	50.6 ± 15.8	49.2 ± 14.7	44.5 ± 13.0	60.59	< **.001**	.68
Accuracy[b]	90.2 ± 9.9	88.8 ± 10.9	87.8 ± 12.1	1.02	.37	.03
Error hit[c]	269.0 ± 284.7	243.5 ± 206.6	242.0 ± 199.8	0.23	.73	.01
Gross hit[c]	2532.5 ± 789.6	2460.1 ± 735.3	2221.7 ± 650.3	65.21	< **.001**	.69
Net hit[c]	2306.8 ± 791.1	2216.6 ± 782.1	1979.7 ± 705.1	41.81	< **.001**	.59

Note. [a]Words per minute (wpm); [b]Percentage (%); [c]Numbers; [d]Statistical significance was set at $p < .05$; Bold indicates significant items

APPENDIX R

POST-HOC ANALYSIS OF TASK PORDUCTIVITY BETWEEN THREE LAPTOP WORKSTATION SETUPS

Body region	Post-hoc analysis	Mean difference	P^c
Net speed[a]	Desktop sitting vs. Lying supine	1.8	.10
	Desktop sitting vs. Chair sitting	6.5	< **.001**
	Lying supine vs. Chair sitting	4.7	< **.001**
Gross speed[a]	Desktop sitting vs. Lying supine	6.0	< **.001**
	Desktop sitting vs. Chair sitting	1.4	< **.001**
	Lying supine vs. Chair sitting	-4.6	< **.001**
Gross hit[b]	Desktop sitting vs. Lying supine	72.3	**.04**
	Desktop sitting vs. Chair sitting	310.8	< **.001**
	Lying supine vs. Chair sitting	238.5	< **.001**
Net hit[b]	Desktop sitting vs. Lying supine	90.2	.10
	Desktop sitting vs. Chair sitting	327.1	< **.001**
	Lying supine vs. Chair sitting	237.0	< **.001**

Note. [a]Words per minute (wpm); [b]Numbers; [c]Statistical significance was set at $p < .05$; Bold indicates significant items

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