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The effects of work surface hardness on mechanical stress, muscle activity, and wrist postures

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Abstract.
BACKGROUND: Contact pressure is a risk factor which can contribute to musculoskeletal disorders.
OBJECTIVE: The objective of the present study was to determine whether a work surface with a soft, pliable front edge could reduce contact pressure, muscle activity, and subjective musculoskeletal comfort, and improve wrist posture relative to a conventional, hard work surface.
METHODS: In a repeated-measures blinded experiment with eighteen subjects (8 females and 10 males), contact pressure, wrist posture, typing productivity, perceived fatigue, wrist and shoulder muscle activity, and subjective comfort were compared between the two different work surfaces during keyboard use, mouse use and mixed mouse and keyboard use.
RESULTS: The results showed that across the three modes of computer work, the contact pressure was lower on the soft-edge work surface compared to the conventional work surface (p's < 0.03) and subjects reported to have less perceived fatigue in the forearms and wrists. No differences in muscle activity, wrist posture, and subjective comfort were measured between the two work surfaces.
CONCLUSIONS: Given the significant reduction in contact pressure and corresponding lower ratings in perceived fatigue, the soft-edge work surface subjectively and objectively improved measures of contact stress which may reduce physical exposures associated with the onset and development of musculoskeletal disorders.

Keywords: Electromyography, electrogoniometer, contact pressure, office ergonomics

1. Introduction

Despite debates on the causality, studies have shown that there may be an association between computer work and musculoskeletal disorders (MSDs) in the upper extremities [1–4]. Although the injury pathologies are not fully understood, these MSDs are assumed to develop from the accumulation of micro trauma to the soft tissues such as muscles, tendons, ligaments, and nerves over time [3]. Physical or biomechanical risk factors for computer-related MSDs include repetition, force, contact pressure, posture, and usage duration [5–7].

Among the musculoskeletal symptoms, previous studies have consistently shown that the neck and shoulders are the most commonly affected regions [2, 4, 8–19]. Some studies found that lack of arm/wrist support increased neck and shoulder discomfort with higher muscle activity and more extreme postures

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during computer use [13, 16, 20–23]. These studies provide evidence that arm/wrist support may lower muscle activity on the neck and shoulder muscles and promote more neutral wrist postures.

However, upper extremity support should be carefully provided as the external contact pressure associated with resting the wrists and/or forearms on the front edge of a work surface has been identified as a physical risk factor [24, 25]. Keyserling et al. [26] identified contact pressure as one of the six generic categories of ergonomic risk factors associated with work-related MSDs; therefore, many studies have investigated its effects on MSDs in various occupational settings [27–29]. Previous studies have shown that external pressure, applied to the palm and flexor retinaculum of the hand, can increase carpal tunnel pressure [24, 30–32]. The increased intra carpal tunnel pressure has been shown to alter nerve function and structure in human and animal models [33–37].Therefore, prolonged contact pressureduring computer use may elevate pressure levels inside the wrists and lead to onset and development of musculoskeletal symptoms and/or disorders, especially carpal tunnel syndrome [34, 37–39]. A recent study [40] showed that concentrated contact pressure around the pisiform area during computer mouse use was associated with ulnar-side wrist pain.

With contact pressure as known risk factor, the aim of the present study was to determine whether a work surface with a softer, pliable leading front edge could reduce contact pressure and muscle activity, and improve wrist posture and subjective musculoskeletal comfort relative to a conventional, hard work surface.

2. Methods

2.1. Subjects

Eighteen subjects (8 females and 10 males) with no history of upper extremity MSDs was recruited to participate in the study through e-mail solicitations. All subjects were experienced computer users who could touch type at least 40 words per minutes (WPM). The average age of subjects was 24.8 (ranging from 20 to 37); and seventeen were right hand dominant. The experimental protocol was approved by the University's Human Subjects Committee and all subjects gave their written consent prior to their participation in the study.

2.2. Experimental design

In the repeated-measures laboratory experiment, contact pressure, muscle activity, wrist posture, perceived fatigue, and comfort were measured while subjects performed a series of the four different simulated computer tasks for approximately 30 minutes on two work surfaces. As can be seen in Fig. 1, the two work surfaces used in this study were covered with the pressure sensitive mat (shaded gray area) on which a keyboard and mouse were placed. Given the work surfaces were covered, the subjects were blinded and did not know anything about the composition of the work surface under the pressure sensitive mat. There was a 5-minute break between the testing of the two work surfaces to minimize any residual fatigue effects and the order of the two work surfaces was randomized.

Prior to the experiment, the chair and work surface was adjusted to match each subject's anthropometry in accordance with ANSI/HFES standards (2007). The keyboard was placed such that the distance between the keyboard front edge and the work surface edge was approximately 10 cm to provide wrist support via the work surface with the alphanumeric portion of the keyboard centered on the centerline of the subject's body (Fig. 1). Demographic and hand anthropometric data including index finger length and index finger width were collected. Index finger length was measured from palmar proximal metacarpophalangeal crease to tip of finger and index finger width was measured at the proximal interphalangeal joint. Then, using a non-test work surface, subjects familiarized themselves with the computer tasks that they were going to perform on each work surface, these tasks included: an exclusive keyboard task – typing; an exclusive mouse task – an omni-directional point-and-click task; and two mixed mouse and keyboard tasks – an intranet web browsing task and text-editing task. The order of these four tasks was randomized

2.2.1. Keyboard task

During the keyboard task, a computer program designed to teach touch-typing (Mavis Beacon Teaches Typing Platinum – 25th Anniversary Edition; Broderbund Software Inc.; Eugene, OR; USA) was used to display text for the subject to type and record subject typing performance. The text used was taken from Grimm's Fairy Tales and had Flesch-Kincaid reading levels between 5.1–5.7 indicating a 5th-grade reading level. The subjects only used the keyboard during the typing task.

Fig. 1. The soft, pliable edge work surface (left) and the conventional hard work surface (right). The gray area shows the location of the pressure sensitive mat which concealed the difference between the two work stations.

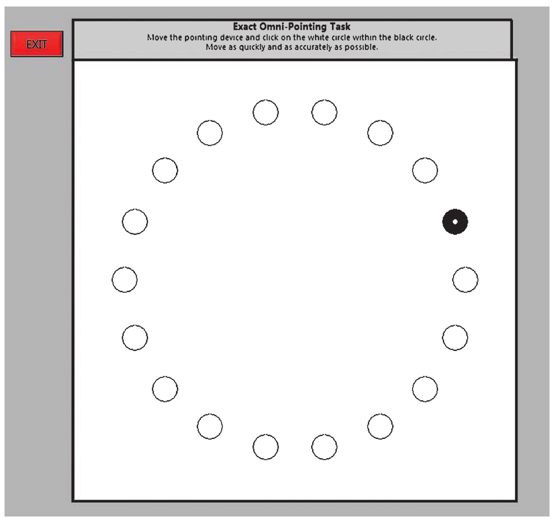

Fig. 2. University of Washington's pointing device performance assessment program for the omni-directional mouse task with center-to-center inter target distances and target width of 142 mm and 12 mm, respectively. The white dot of the highlighted circle represents the center of the circle.

2.2.2. *Mouse task*

For the mouse task, as can be seen in Fig. 2, subjects alternately clicked on 18 evenly spaced targets arranged in a circle using the University of Washington's pointing device performance assessment program [41]. At random, one of the 18 circles was highlighted and the subject was asked to move the mouse inside the highlighted circle and click as close to the center as possible (indicated by the white dot at the center of the highlighted black circle on Fig. 2) while trying to balance speed and accuracy. Upon clicking on the highlighted circle, another circle would randomly be highlighted and the task continued. The program logged the movement time of the subject from one circle to the nextand the accuracy in clicking close to the center of the highlighted circle (distance from the center of the circle). The subjects only used the mouse during the omni-directional point-and-clicktask.

2.2.3. *Mixed mouse and keyboard tasks*

For a period lasting 10-minutes, subjects performed Harvard University's web-browsing task program [11] using the mouse to navigate and findweb pages and then using the keyboard to answer questions associated with web-content presented on the screen. A second mixed mouse and keyboard task was a 10-minute, Microsoft-Word based text-editing task (Microsoft Word 2010, Microsoft Corporation; Redmond, WA; USA). In this task, spelling errors, spacing errors, punctuation errors, and formatting errors were randomly inserted throughout an 18-page document; and subjects used both the mouse and keyboard to correct the errors as they read through the text.

2.3. *Contact pressure*

As can be seen in Fig. 3, the contact pressure from each work surface was collected at 5 Hz using a pressure sensitive mat (Xsensor X3 Pro; Xsensor Technology Co.; Calgary; Canada). The accuracy of the pressure sensitive mat was validated in a previous study [42]; the absolute mean pressure errors over a 0.097 to 3.867 Newton/cm^2(N/cm^2) range was less than 10% over the designed seeming area (the grid in Fig. 3) of the pressure sensitive mat.

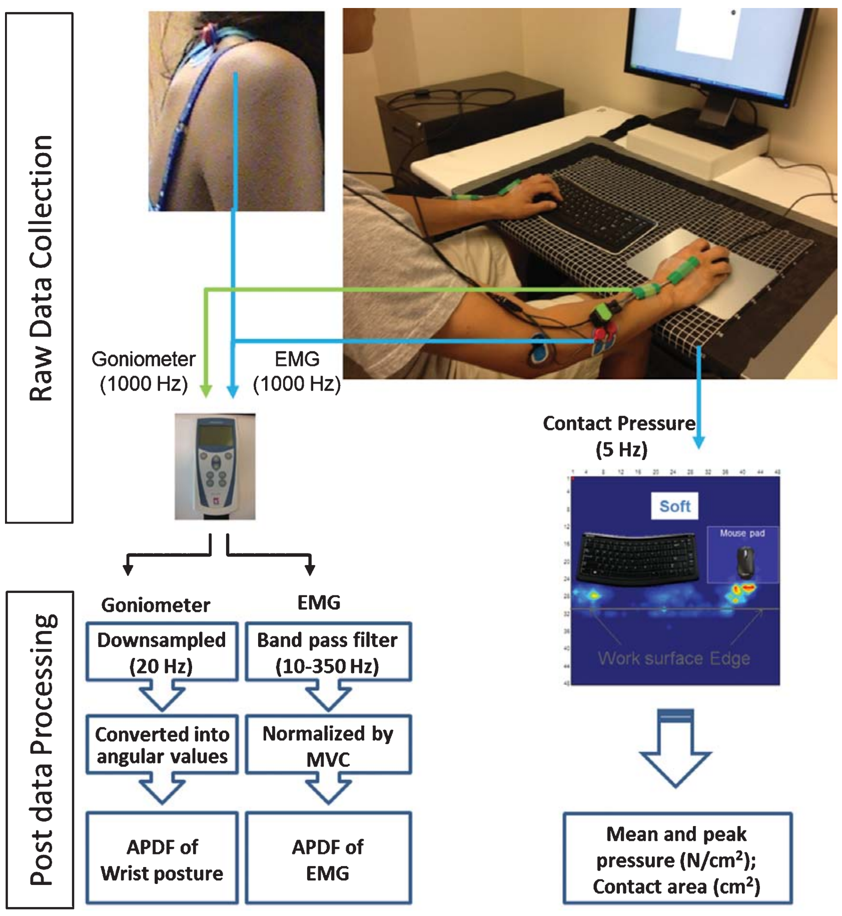

Fig. 3. Experimental set-up and data acquisition system.

2.4. Muscle activity

Muscle activity (EMG) was recorded from the right extensor carpi ulnaris (ECU), right flexor carpi ulnaris (FCU), and right/left trapezius (TRAP) muscle. The ECU/FCU muscle identification and electrode placement were performed according to the methods by Basmajian et al. and Perotto and De Luca [43, 44] while electrode placement for TRAP muscle was done using the methods prescribed by Jensen et al. [45]. The ECU electrodes were located at two-thirds of the distance from the dorsal surface of base of fifth metacarpal to the lateral epicondyle of the humerus on the dorsal aspects of the forearm. Similarly, the FCU was located two fingerbreadths volar to ulnar at two-thirds of the distance from the pisiform to the common tendon from medial epicondyle of humerus [43, 44]. The ground electrodes for ECU and FCU muscle were placed on the lateral and medial epicondyles, respectively. The active electrodes for the TRAP muscle were placed 2 cm lateral to the halfway point between C7 and the right acromium process while the ground was placed on C7 [45].

Prior to applying EMG electrodes to the skin, the electrode contact area was prepared by shaving the area with a razor (BRN1312; Medline; Mundelein, IL, USA) and cleaning the skin's surface with Alcohol Prep Pads (Dynarex; Orangeburg, NY, USA) to reduce skin impedance. Then, disposable Ag/AgCl surface electrodes, which had an 8-mm diameter pick up area (Blue Sensor N-00-S; Ambu; Ballerup, Denmark), were placed with a 20-mm inter-electrode spacing over the three muscles. EMG signals were recorded using a digital data logger (Mega ME6000; Mega Electronics; Kupio, Finland) at a sampling rate of 1000 Hz.

After collecting the raw EMG data, a band pass filter of 10–350 Hz was applied. The filtered EMG data from the ECU, FCU, and TRAP muscles were normalized as a percentage of each muscle's Maximum Voluntary Contraction; thenthe 10th$^{\%tile}$ (static), 50th$^{\%tile}$ (median) and 90th$^{\%tile}$ (peak) amplitude probability density function (APDF) muscle activities were calculated [46]. To obtain the Maximum Voluntary Contractions (MVCs), subjects were instructed to extend their wrists with ulnar deviation against isometric resistance (ECU) and to flex their wrist down with ulnar deviation against isometric resistance (FCU) with verbal encouragement. To obtain TRAP MVCs, isometric resistance was applied as subjects performed a continuous shoulder shrug with their arms at their sides and without bending or twisting at the hips/waist [47, 48]. Each contraction time lasted between three and five seconds [49]. Three MVCs were collected from which the maximum RMS signal over a 1 second period was identified and used to normalize the EMG data.

2.5. *Wrist posture*

Wrist postures including flexion/extension and radial/ulnar deviation were measured from both hands using biaxial electrogoniometers (Model SG-75; Biometrics Ltd; Newport, UK). The attachment and calibration of the electrogoniometers were performed using the methods prescribed by Johnson [50, 51]. The raw goniometer data were synchronously collected with the EMG signals at 1000 Hz using the same aforementioned digital data logger (Mega ME6000; Mega Electronics; Kupio, Finland). After data collection, the raw goniometer data were parsed and down-sampled to 20 Hz. Then the 5th, 50th, and 95th percentile values were calculated for the flexion/extension and radial/ulnar deviation planes [52]. The 5th and 95th percentiles represented the extreme wrist postures while the 50th percentile represented the central tendency of the wrist posture. Lastly, the ranges of motion in the flexion/extension and radial/ulnar deviation planes were calculated based on the difference between 95th and 5th percentiles [52].

2.6. *Perceived fatigue subjective comfort*

Before and after the computer tasks on each work surface, perceived fatigue ratings were measured on hand, wrist, forearm, shoulder, and neck using a Borg CR-10 scale [53]. The Borg CR-10 questionnaire measures subjective perception of muscle fatigue with 0 indicating no fatigue and 10 the most severely fatigue rating.

After the computer tasks on each work surface, subjective comfort ratings were collected using a slightly modified Likert scale questionnaire adapted from the ISO keyboard comfort questionnaire (ISO9241-410; 2008). The ISO comfort questionnaire measures subjective comfort on variable aspects including upper extremity comfort, usability and productivity with a 7-point scale (1 being least comfortable and 7 being most comfortable). Verbal anchors were used at both ends of each scale.

2.7. *Data analysis*

A mixed model with restricted maximum likelihood estimation (REML) in JMP (Version 9; SAS Institute Inc.; Cary, SC, USA) was used to determine whether different work surfaces affected contact pressure, muscle activity, wrist posture, perceived fatigue and productivity. Any statistical significance was followed-up with a *Tukey-Kramer post-hoc* test. *Friedman* tests with *post-hoc* multiple comparison in R (R 2.13.2, Development Core Team) were used to determine whether there were any differences between work surfaces in subjective comfort and preference. All data are presented as mean and standard error; and significance was noted when Type I error was less than 0.05.

3. Results

3.1. *Contact pressure*

Mean and peak contact pressure (N/cm^2) as well as contact areas (cm^2) were calculated to determine whether there are any differences between the two different work surfaces. The soft-edge work surface showed approximately 12% lower mean contact pressure than the hard-edge work surface ($p = 0.02$) across the whole 30-minutes of the various computer tasks (Fig. 4a). During the keyboard task ($p = 0.007$), the mean contact pressure was 17% lower on the soft, pliable-edge work surface when compared to the conventional hard work surface. Although there were no significant work surface effects for the mouse ($p = 0.28$) and the web-browsing ($p = 0.59$) and text editing ($p = 0.25$) tasks, the mean pressure on the soft-edge work surface was consistently lower across all the tasks. A heat map of the contact pressure is shown in Fig. 5 providing graphical comparisons of the various tasks.

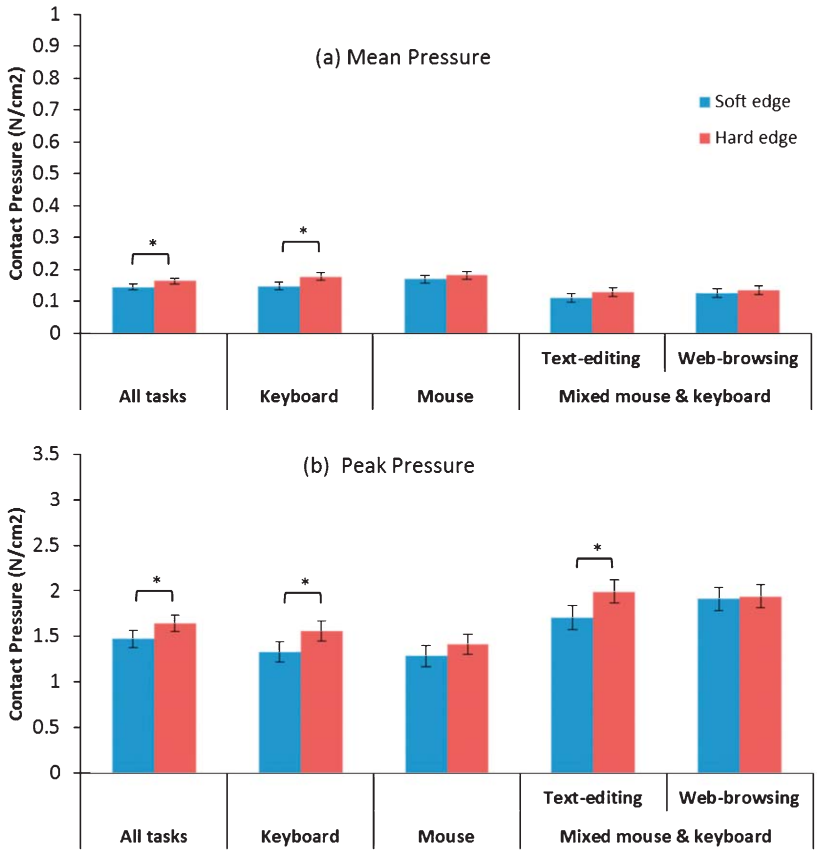

Fig. 4. Mean and Peak contact pressure (N/cm^2) comparisons by task and work surface: (a) peak pressure and (b) mean pressure [N = 18]. Asterisks denote statistical significance.

Similarly, across all tasks, peak contact pressure was about 11% lower ($p = 0.048$) on the soft, pliable-edge work surface compared to the conventional, hard work surface (Fig. 4b). During the keyboard and text editing tasks, the peak contact pressure was 15% ($p = 0.02$) and 14% ($p = 0.03$) lower respectively on the pliable, soft-edge work surface compared to the comparable tasks performed on the hard-edge work surface.

Across the whole 30-minutes of computer work, the pliable, soft-edge work surface had a larger total contact area ($p = 0.001$) compared to the conventional, hard-edge work surface (Fig. 6). While there was no work surface effects found on total contact areas during the keyboard and mouse tasks, the total contact areas were larger on the soft-edge work surface when compared to the hard-edge surface during the text-editing and web-browsing tasks ($p = 0.04$ and 0.07, respectively). Similarly, both mean and peak contact areas were consistently larger on the soft-edge work surface compared to the hard-edge work surface ($p = 0.002$ and 0.001, respectively). These differences on the mean and peak pressure contact area were more pronounced during the text-editing ($p = 0.04$) and web-browsing tasks ($p = 0.07$).

3.2. *Muscle activity*

The 10th, 50th, and 90th percentile values of muscle activity were calculated (as a %MVC) to compare muscle activity levels between the two work surfaces in the right extensor carpi ulnaris (ECU), right flexor carpi ulnaris (FCU), and left and right trapezius (Left TRAP and Right TRAP) muscles. Due to technical problems, muscle activity data collected from sixteen subjects were analyzed. There were no differences in ECU and FCU muscle activity between the work surfaces during the entire 30-minute computer task (Fig. 7(a)). Similarly, the left and right TRAP muscle activity was not

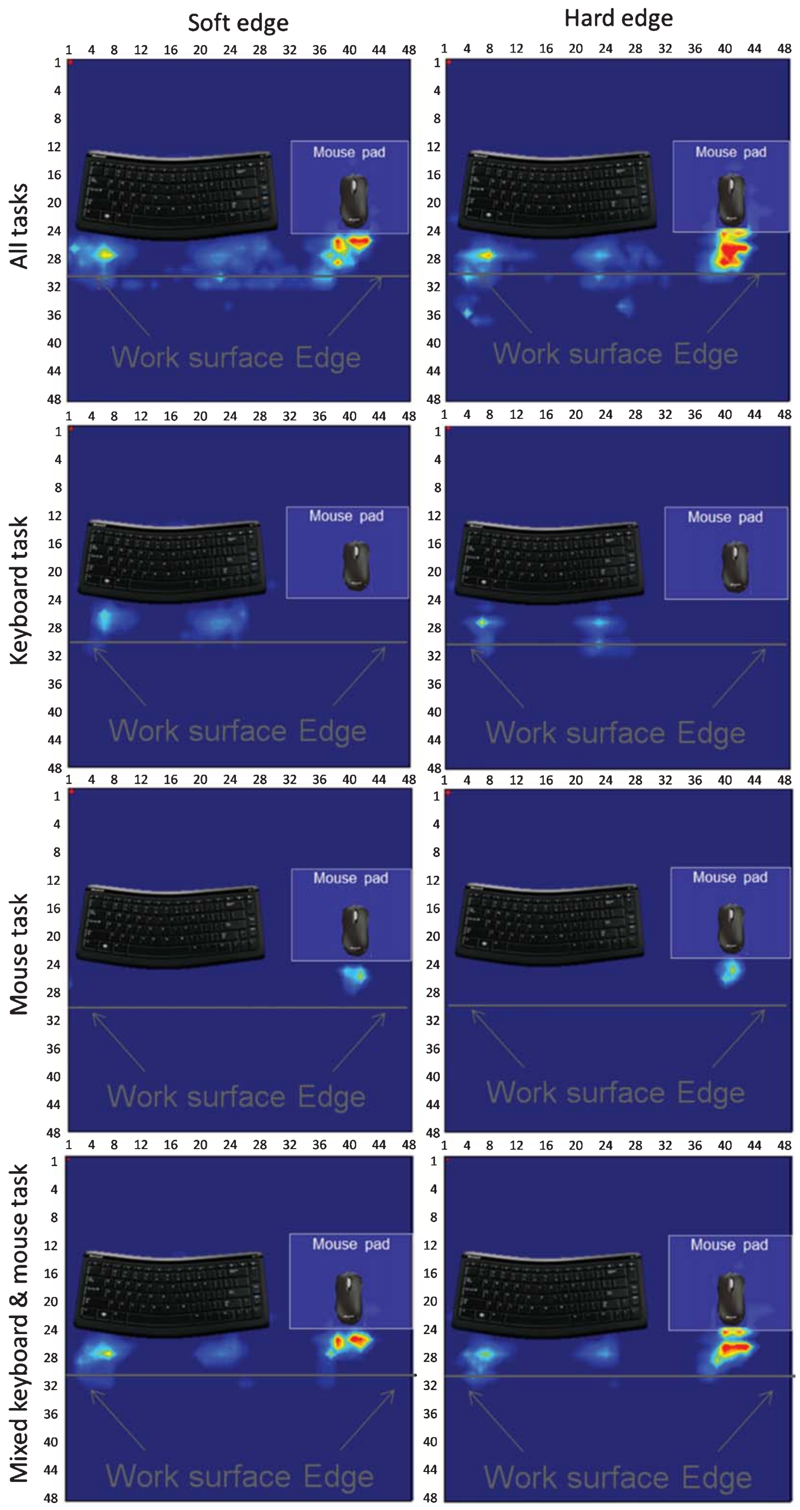

Fig. 5. Graphical comparisons across tasks of the contact pressure between the soft, pliable-edge work surface (left) and the conventional hard work surface (right). The numbers in the picture margins refer to grid locations on the pressure sensitive mat.

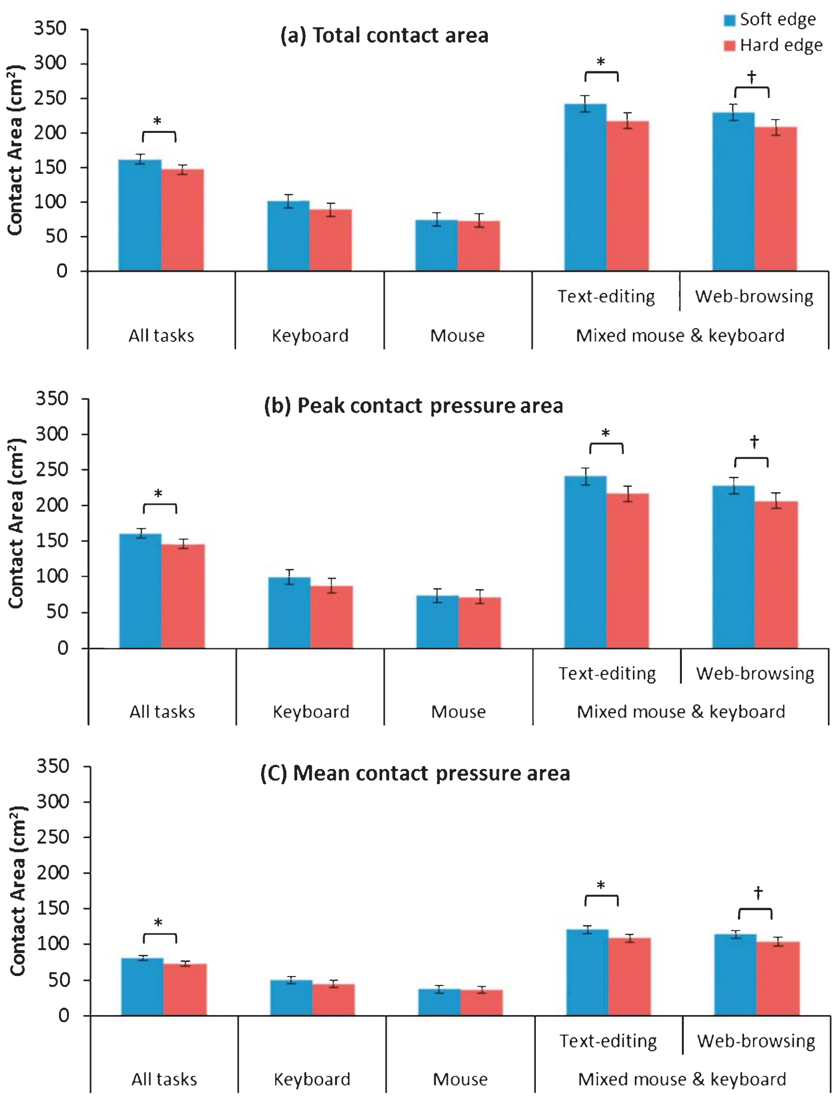

Fig. 6. Comparisons of contact areas between computer tasks: (a) total contact area where non-zero pressure was applied; (b) peak contact pressure area where peak contact pressure was applied; (c) mean contact pressure area where mean contact pressure was applied [N = 18]. Asterisks and crosses denote statistical significance at $\alpha = 0.05$, and 0.10, respectively.

different between the work surfaces (Fig. 7(a)). During the keyboard task (Fig. 7(b)), however, ECU muscle activity was slightly higher on the soft-edge work surface when compared to that on the hard-edge work surface ($p = 0.08$).

ECU muscle activity was approximately two times higher than FCU muscle activity ($p < 0.0001$). Specifically, the 90th percentile value of ECU was approximately 29.1%MVC as compared to 16.9% MVC during the keyboard task (Fig. 7). The same trends were also found for different tasks. Moreover, the ECU and FCU muscle activity was up to 60% higher during the keyboard task as compared to other mouse-intensive tasks such as mouse and web-browsing tasks (p's < 0.001) (Fig. 7). The significantly higher 90th percentile values on wrist muscle activity indicated that the keyboard task was much more dynamic than other tasks where a computer mouse used more extensively (Fig. 7).

3.3. Wrist posture

The 5th, 50th, and 95th percentile values of electrogoniometry data were calculated to determine whether

Fig. 7. Comparisons by work surface type of 10th, 50th, and 90th percentile muscle activity in extensor carpi ulnaris, flexor carpi ulnaris, and trapezius muscles by task [N = 16]. The cross denotes statistical significance at $\alpha = 0.10$.

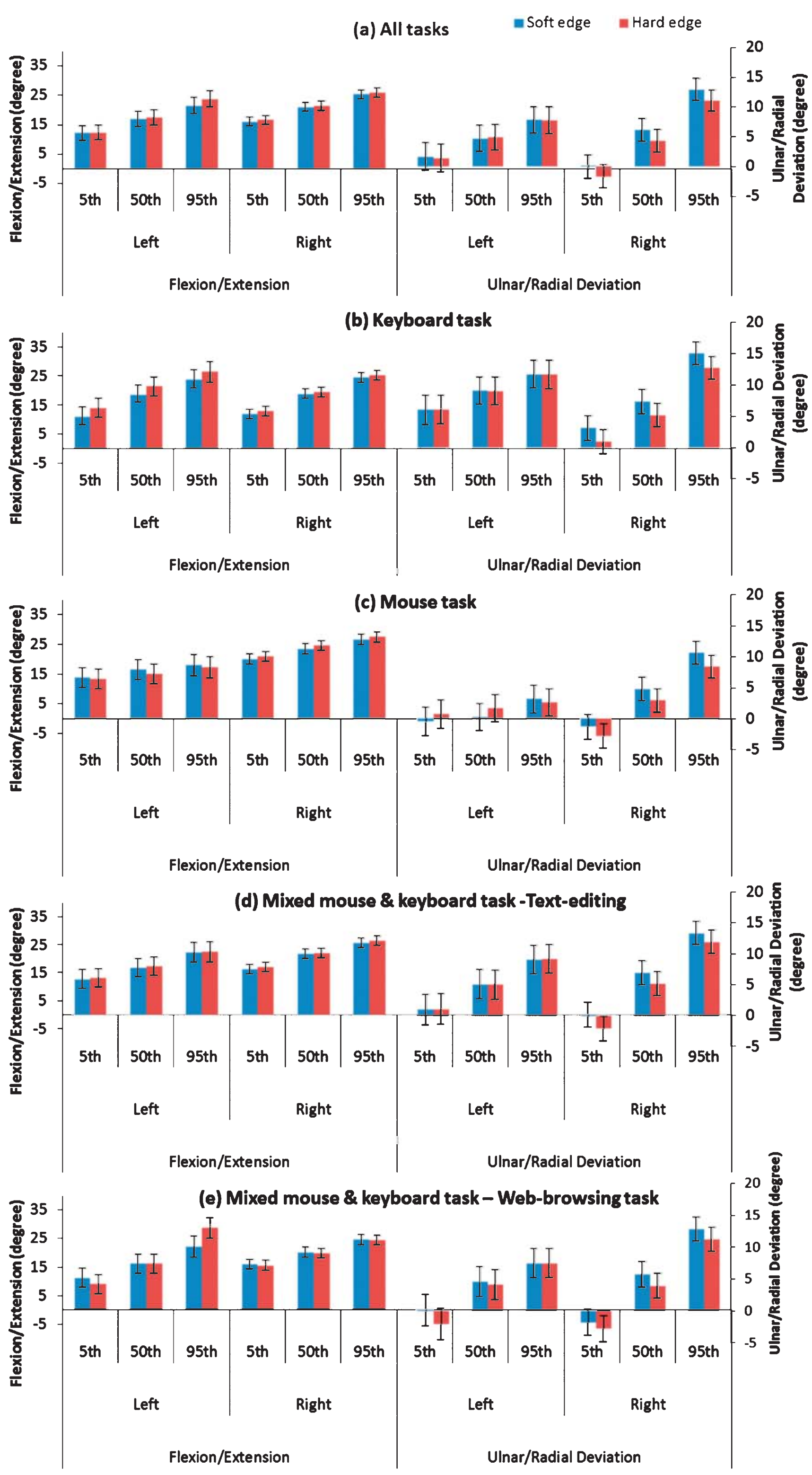

Fig. 8. Comparisons of wrist postures (5th, 50th, and 95th percentile) by the workstations and task [N = 16]. Asterisk denotes statistical significance at $\alpha = 0.05$.

Table 1
Mean (SE) changes in perceived fatigue, ratings of subjective comfort, and performance measures after working 30 minutes on each work station. For perceived fatigue, Borg CR-10 scale was used with 0 indicating no fatigue and 10 the most severely fatigue rating. For subjective comfort, a seven point Likert Scale was used with 1 indicating the least preferable rating and 7 the most preferable rating [N = 18]

			Work surface		
			Soft edge	Hard edge	*p*-value
Changes in Perceived fatigue (Post-Pre)		Hand	0.5 (0.2)	0.5 (0.2)	0.97
		Wrist	0.1 (0.2)	0.8 (0.2)	**0.01****
		Forearm	0.2 (0.2)	0.7 (0.2)	0.13
		Shoulder	0.5 (0.2)	0.8 (0.2)	0.20
		Neck	0.8 (0.2)	0.8 (0.2)	0.77
Subjective comfort		Hand/Wrist	5.3 (0.3)	5.1 (0.3)	0.45
		Arm/Elbow	5.3 (0.3)	5.0 (0.3)	0.22
		Shoulder/Neck	4.6 (0.3)	4.9 (0.3)	0.31
Performance	Keyboard	Typing speed (WPM)	57.5 (3.6)	58.1 (3.6)	0.28
		Accuracy (%)	89.9 (2.5)	95.7 (2.4)	**0.09***
	Mouse task	Movement time (sec)	1.4 (0.1)	1.4 (0.1)	0.51
		Accuracy (mm)	0.8 (0.1)	1.0 (0.1)	0.14

Asterisks denote statistical significance (**: $p < 0.05$; *: $p < 0.1$).

work surfaces affected wrist postures. The results showed that wrist postures including flexion/extension and ulnar/radial deviations were not affected by the different work surfaces; however, during the web-browsing task, the 95th percentile left wrist extension was greater on the hard-edge work surface compared to the soft-edge work surface (Fig. 8).

The wrist postures were also compared across the various computer tasks. The 5th, 50th, and 95th percentile values of ulnar deviation showed that left wrist had greater ulnar deviation during the keyboard task compared to the mouse task (p's < 0.0001). The 5th and 50th percentile values of right wrist flexion and right wrist extension indicated that the mouse task resulted in approximately 20% greater wrist extension than the keyboard task (p's < 0.0006). Furthermore, the keyboard task showed greater range of wrist motion (approximately 12 degrees) than the mouse task (approximately 5-6 degrees).

3.4. Perceived fatigue, comfort, and performance

Perceived fatigue measures (Borg CR-10) showed that less perceived fatigue developed in wrist during the computer tasks with the soft-edge work surface ($p = 0.01$) whereas work surface did not affect perceived fatigue in other body regions (Table 1). There was also no difference in subjective comfort between the work surfaces. Although typing accuracy was marginally better on the hard-edge work surface ($p = 0.09$), there was a minimal work surface effects on performance during typing and pointing tasks.

4. Discussion

The main objective of this study was to determine whether different surface treatments on the leading edge of a work surface affected contact pressure, muscle activity, wrist posture, performance, and perceived fatigue and subjective comfort during computer use. The results showed that soft-edge work surface reduced contact pressure by creating a larger contact area under the wrists, which was linked with significantly less perceived fatigue in the wrists after 30 minutes of computer use. However, little to no differences were found between work surfaces in muscle activity, wrist postures, productivity, and subjective comfort.

The present study found that mean and peak contact pressure was significantly lower on the soft-edge work surface due to larger contact areas being created under the wrists during the computer work (p's < 0.05). Previous studies showed that contact pressure is a biomechanical risk factor associated with musculoskeletal disorders (MSDs) [24–26]. Some studies showed that the external contact pressure over the wrist region could increase intra carpal tunnel pressures and therefore increase a risk for MSDs, especially carpal tunnel syndrome [24, 30–32]. A recent study showed that increased contact pressure on the wrist region (i.e. pisiforms) during computer mouse use was associated with musculoskeletal discomfort including numbness, tingling, and pain in the ulnar region where the wrist contacts the work surface [40]. Therefore, the reduced contact pressure may help reduce some of the adverse potential biomechanical exposures that may be associated with MSDs during computer work.

The objective measures of lower contact pressures with the soft-edge work surface was complimented by subjectively reported lower level of perceived fatigue in the wrist ($p = 0.01$), forearms ($p = 0.13$) and shoulders ($p = 0.20$) on the soft-edge work surface when compared to the hard-edge work surface.

Muscle activity was not affected by the different work surfaces; however, the muscle activity differed between the different computer tasks. The keyboard task evoked higher ECU and FCU muscle activity than any of the other tasks, especially for 90th percentile values. Dennerlein and Johnson [11] also found that the wrist muscle activity was higher during keyboard use when compared to mouse use. As Dennerlein and Johnson [11] discussed, this may be due to the dynamic nature of the keyboard task, which consists of highly repetitive finger and wrist movements. Since the 90th percentile values represent dynamic muscle activity [46], the corresponding muscle activity was found to be relatively higher during keyboard use compared to the other tasks.

Extensor carpi unlaris (ECU) muscle activity was approximately two times higher than flexor carpi unlaris (FCU) muscle activity. Dennerlein and Johnson [11] also found that wrist extensor muscle activity was higher compared to wrist flexor muscle activity. This may be due to the strength differences between the muscles. Previous studies have showed that flexor muscles are significantly stronger than the extensor muscles [54, 55]. Therefore, when the force exerted from those muscle groups are similar, since the extensor muscle are smaller in cross-sectional area, they tend to have relatively higher muscle activity when compared to the flexor muscles. Due to higher level of muscle activity, the ECU muscles may be at higher risk to musculoskeletal symptoms and/or injuries. This finding is in line with previous findings that extensors are more prone to injury [56].

The results also demonstrated that the wrist posture differed across the various computer tasks. The keyboard task resulted in greater ulnar deviation on the left wrist than the mouse task whereas the mouse task caused greater wrist extension than the keyboard task, this is in line with previous studies [11]. Ulnar deviation and wrist extension have been shown to increase intra carpal tunnel pressure [33, 37] and tendon force [35], which have been associated with carpal tunnel syndrome and tendon injuries. Therefore, the contact pressure and non-neutral wrist postures could collectively increase risks for MSDs.

Furthermore, the keyboard task showed greater range of wrist motion (approximately 12 degrees) than the mouse task (approximately 5-6 degrees). The smaller range of wrist motion and less dynamic muscle activity implies that mouse use is relatively more static and therefore may induce more static muscular loading and wrist posture. This static loading and postures are well documented as risk factors for MSDs during computer use [5, 14, 63]. This finding supports many epidemiological studies that have shown that mouse use has the stronger association with MSDs [5].

The main limitations of the present study include simulated computer task and the relatively short duration of exposure (30 minutes on each work surface). Although the simulated computer tasks were developed to reflect actual computer use, they were not real occupational computer tasks. However, this standardized and controlled computer task allowed us to perform a relatively clean "apples-to-apples" comparison between the two work surfaces. Thirty minutes on each of the work surfaces may not be sufficient enough to determine whether the reduced contact pressure help promote musculoskeletal comfort. This may be the reason why the reduced contact pressure was not reflected in the subjective comfort ratings. Therefore, in subsequent studies, it may be beneficial to conduct a longitudinal study to investigate whether there are any long-term effects of reduced contact pressure on musculoskeletal outcomes.

In conclusion, the present study demonstrated that soft-edge work surface could distribute contact pressure over larger contact areas and lower contact pressure where the wrists are in contact with the work surface. The objective measurement of contact pressure was complimented by lower subjective reporting of perceived fatigue in the wrists. Although this study did not find any relationship between reduced contact pressure and subjective comfort ratings, the soft-edge work surface may still be of benefit since it was shown to significantly reduce contact pressure, which is one risk factor which can contribute to the onset and development of computer-related musculoskeletal disorders.

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