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The relationship between musculoskeletal symptoms, postures and the fit between workers' anthropometrics and their computer workstation configuration

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Abstract.
OBJECTIVE: Awkward postures during computer use are assumed to be related to the fit between the worker and the workstation configuration, with greater mismatches leading to higher levels of musculoskeletal symptoms (MSS). The objective of this study was to examine if chronic MSS of the neck/shoulder, back, and wrist/hands was associated with 1) discrepancies between workstation setups and worker anthropometrics and 2) workers' postures.
PARTICIPANTS: Secondary analysis on data collected from a randomized controlled cross-over design trial ($N = 74$).
METHOD: Subjects' workstation configurations, baseline levels of MSS, working postures, and anthropometrics were measured. Correlations were completed to determine the association between postures and discrepancies between the worker anthropometrics and workstation configuration. Associations were examined between postures, workstation discrepancies and worker MSS.
RESULTS: There were only 3 significant associations between worker posture and MSS, and 3 significant associations between discrepancies in worker/workstation set-up and MSS.
CONCLUSION: The relationship between chronic MSS and the workers computer workstation configuration is multifactorial. While postures and the fit between the worker and workstation may be associated with MSS, other variables need to be explored to better understand the phenomenon.

Keywords: Computer workstation, musculoskeletal discomfort, workstation assessment, ergonomics

1. Introduction

Computer use is associated with increased incidence of musculoskeletal symptoms (MSS), such as pain, numbness, or aching [1–3]. MSS are often chronic conditions, lasting more than 3 months, and can have significant effects on productivity [4]. While the causes of MSS, particularly chronic MSS, are multifactorial [5], the relationship between the set-up of the computer workstation and its effect on the postures of the computer operator has been identified as one risk factor for MSS [6].

MSS have been associated with computer operators' postures [7]. The ANSI/HFES 100–2007 [6] standards for the engineering of computer workstations recommend: 1) shoulder abduction angle less than 20 degrees; 2) shoulder flexion angle less than 25 degrees; 3) elbow angle between 70 and 135 degrees; wrist flexion/extension angles less than 30 degrees, and 4) torso to thigh angle equal to or greater than 90 degrees. Current intervention strategies have often focused on helping computer operators with postures outside these parameters to achieve these postures during computer use [8–14] by adjusting the workstation configuration. However, the literature supporting the effectiveness in reducing MSS by achieving these postural benchmarks

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through workstation adjustment has provided mixed results [11,13,15–17]: some studies support the intervention technique and others do not.

Postures outside recommended parameters (awkward postures) during computer operation are assumed to be influenced by the fit between the workstation configuration and the anthropometrics of the computer operator. The underlying assumption that guides ergonomics is that if the demands of the work do not match the capabilities of the worker, stress can occur which can cause acute MSS, and aggravate chronic MSS [18,19]. Thus, it is postulated that if the computer workstation configurations do not match the anthropometrics of workers it will lead to awkward postures. These awkward postures will place stress on the system, and will be associated with higher levels of MSS.

Awkward postures have become a marker for discrepancies between the worker and the workstation and have been reported to be a risk factor for MSS [5]. While awkward postures during computer operation have been examined extensively [8,11,14,20], there are very few studies that have included anthropometric measures and how these relate to the workstation set-up [20–22]. Green and Briggs [21,22] examined the anthropometrics between "sufferers and non-sufferers" and reported that the workstation equipment of female computer operators might not be configured appropriately to their users. Marcus et al. [20] reported that a keyboard higher than the seated elbow height was associated with greater risk for MSS. This underlying assumption in workstation intervention strategies, that MSS can be reduced by eliminating discrepancies between the worker and the workstation, should be examined further to determine if the basic premise that postures and discrepancies are associated, and that discrepancies and postures are associated with MSS.

The purpose of this study was to examine if chronic MSS of the neck/shoulder, back, and wrist/hands was associated with 1) discrepancies between workstation setups and worker anthropometrics and 2) workers' postures. The three research questions were: 1) are there significant associations between discrepancies between anthropometrics/workstation set-up and postures; 2) are there significant associations between discrepancies between the anthropometrics/workstation set-up and worker reports of MSS; 3) are there significant associations between postures and worker reports of MSS.

2. Methodology/participants

2.1. Participants

The Institutional Review Board at the University of Pittsburgh approved this study. Written informed consent was obtained from all study subjects prior to data collection.

This is a secondary analysis on data collected at the baseline of a randomized controlled cross-over design trial conducted in the United States (parent study), which examined the effect of alternative keyboard use on musculoskeletal discomfort. To be eligible for the parent study subjects had to be adults aged 18–65 years, spend at least 20 hours per week on a primary computer, and report at least minimal discomfort (2 or greater on a 10 point visual analog scale) in at least one upper extremity body part within the past 6 months. Exclusion criteria were current use of an alternative keyboard, a serious upper extremity injury, and rheumatic disorders.

Subjects were recruited from the Faculty and Staff of the University of Pittsburgh. Recruitment methods were study flyers, a university wide telephone broadcast message, a university mass mailing of study flyers to staff, and word of mouth. Subjects worked in a variety of departments, but all used a computer. Workstations and tasks performed on the computer were highly variable.

2.2. Instruments

2.2.1. *Weekly Discomfort Survey* (*WDS*)

Discomfort scores were obtained from the WDS, a self-report questionnaire used in computer workstation intervention studies [11,23]. This survey assesses upper extremity discomfort for the neck/shoulder, back, and left and right elbow/forearm/wrist/hand experienced each week using a 11 point numerical rating scale (NRS) ($0 =$ no pain to $10 =$ unbearable pain). It also examines the effect discomfort has on daily living activities (e.g. sleep, carrying objects, writing), on work productivity, and describes the steps taken to relieve discomfort (e.g. medication, rest). Although the tools itself has not been tested for reliability and validity, the NRS scale used in the study is a common tool in pain measurement [24,25].

Table 1
Mean worker and workstation measurements for the study sample and the U.S. population (cms)

Worker measurements		Sample		Population [28]	
Item	Measurement	Females ($n = 69$)	Males ($n = 5$)	Females	Males
Popliteal height (Calf)	Vertical distance from the floor to the popliteal angle at the underside of the knee[1]	44.7 ± 2.6	48.4 ± 3.3	40.0 ± 2.8	45.0 ± 2.8
Buttock – popliteal length (Thigh)	Horizontal distance from the back of the uncompressed buttocks to the popliteal angle at the underside of the knee	50.8 ± 3.1	53.0 ± 2.7	50.3 ± 5.0	52.4 ± 4.0
Seated elbow height (SElbow)	Vertical distance from the seat to the olecranon	18.6 ± 3.3	19.1 ± 1.5	23.3 ± 2.7	24.5 ± 2.8
Floor – elbow height (FElbow)	Summed Seat Height and Seated Elbow Height	68.2 ± 4.9	69.3 ± 4.4	**	**
Seated eye height (Eye)	Summed Seat Height and the vertical distance from seat to the corner of the eye	118.7 ± 4.7	124.3 ± 7.0	**	**
Workstation measurements					
Item	Measurement	Total ($n = 74$)			
Seat height (Seat)	Vertical distance from floor to edge of seat	49.7 ± 4.3			
Seat pan depth (Pan)	Horizontal distance from the front edge of the seat to the lumbrical aspect of the back rest	45.4 ± 3.0			
Armrest height (Armrest)	Vertical distance from seat to top of armrest	17.0 ± 6.2			
Keyboard height (Keyboard)	Vertical distance from floor to keyboard	69.7 ± 6.5			
Monitor height (Monitor)	Vertical distance from floor to top of monitor	44.9 ± 4.1			

[1] worker wears shoes typically worn at work; **Data depends on the height of the chair the person is seated in, population means are not available.

2.2.2. *Anthropometrics*

Subject's anthropometrics were obtained with a Rosscraft Segmometer 4 (Rosscraft Innovations Inc, CA) or a large Anthropometer (Lafayette Instruments; http://www.lafayetteinstrument.com/). The Rosscraft Segmometer is a 105 cm flexible ruler with a 10.5 cm base pointer and sliding pointer. The base pointer stabilizes the instrument on surfaces while the sliding pointer promotes accurate reading of the length of the object. The Anthropometer is a caliper type instrument. Measurements were taken of subjects seated in a typical office chair in the study laboratory by a single trained research assistant. A description of the measurements used in this study is listed in Table 1 along with the sample mean and population mean for those measurements.

2.2.3. *Workstation configuration*

Subject's computer workstation configurations were measured using the Rosscraft Segmometer 4. Measurements were taken by a single trained research assistant in the subject's workstation prior to the start of the study. Workers primary work task in the workstation was using a computer. Measurements are listed in Table 1.

2.2.4. *Postures*

Lateral view photographs of workers were taken while the workers completed standardized typing tasks in their workstation. The photographs were taken approximately 5 minutes after the start of the typing task to ensure that the workers had settled into their typical working posture. The view encompassed the top of the head to the seat of the work chair. The following anatomic landmarks were marked on the worker prior to taking the photographs to aid with postural calculations: The shoulder acromion, the lateral epicondyle, the ulnar styloid, and the distal aspect of the third metacarpal.

2.3. *Procedure*

Subjects' workstation configuration measurements and baseline levels of musculoskeletal symptoms were obtained. Lateral still photographs (right and left) of subjects were taken as they completed a standa weeks later while they were seated on a standard office chair in the study laboratory.

2.4. *Data processing*

We calculated the floor – elbow height and the seated eye height by summing the seat height obtained at

Table 2
Discrepancy variables

Discrepancy variables	Measurements	Direction of score (positive number)	Risk factor for MSS
Seat/Calf	(Seat height) – (Popliteal height)	Seat height is higher than the calf length	Seat higher than calf length
Pan/Thigh	(Seat pan depth plus 5 cm) – (Buttock to back of knee)	Seat pan length is longer than the thigh length	Seat pan length longer than thigh length
Armrest/SElbow	(Armrest height from seat pan) – (seated elbow height)	Armrest height is higher than the elbow height	Armrest height higher or lower than the elbow height
Keyboard/FElbow	(Keyboard height) – (Floor – elbow height)	Keyboard height is higher than the elbow height	Keyboard height higher than elbow height
Monitor/Eye	(Monitor height) – (Seated eye height)	Monitor height is higher than the eye height	Monitor height higher or lower than eye height

MSS = musculoskeletal symptoms.

subjects workstations with their seated elbow height and seated eye height respectively (Table 1). To obtain the discrepancy values we subtracted the worker height from the workstation set-up height (Table 2). A seat height higher than the popliteal height and a keyboard height higher than a seated elbow height are considered risk factors for MSS [19,20]. Seat pan depths that are longer than the thighs prevent workers from sitting back in their chairs and supporting their backs on the backrests, therefore seat pans should be shorter than the thigh length to ensure that there is no pressure on the back of the legs [19]. We included a 5cm addition to the seat pan depth in the calculations to ensure that seat pan length included leg clearance. We used the absolute values of the differences the monitor/eye height as the literature on this suggests that discrepancies in either direction are potentially risk factors [11,19,23]. Thus, larger discrepancies would indicate greater potential problems, regardless of direction.

Using the anatomic landmarks identified on each worker, we marked angles on the photographic lateral views taken at workers' workstations. We used a goniometer to measure each angle. The following angle definitions were used: the neck angle was formed by a vertical line and the line from the C7 spinous process to the tragus [26]; the shoulder angle was the angle formed by the trunk line and the line of the humerus (formed between the acromion process and the lateral epicondyle) [27]; the elbow angle was formed by the line of the humerus and the line of the forearm (formed between the lateral epicondyle and the radial styloid) [27]; and the wrist extension angle was formed by the dorsal aspect of the forearm and the dorsal aspect of the hand to the third metacarpal. For the elbow, full extension was 180 degrees, so smaller numbers indicated a greater flexion angle of the elbow. For other joints, a larger number indicated greater angles.

3. Data analysis

Data was analyzed using SPSS v.18. Descriptive data was obtained. Preliminary analyses of the MSS scores indicated that they were not normally distributed, so we used Spearman's rho correlations for all scores involving the MSS outcome and Pearson's correlations to determine if there were significant associations between postures and discrepancy variables.

4. Results

The participants included in this secondary analysis were primarily female and white. They used their computer, on average, 6.2 hours per day. Their average pain levels were mild but almost half used pain killers (Table 3).

Significant correlations suggested that larger discrepancies in keyboard heights were associated with greater shoulder postures and smaller elbow and wrist postures (Table 4).

Monitor height discrepancies were significantly negatively associated with right upper extremity (RUE) and left upper extremity (LUE) MSS, and borderline significantly associated with neck MSS ($p = 0.08$). Armrest discrepancies were also significantly negatively associated with neck MSS (Table 5). Neck flexion posture was significantly negatively associated with RUE MSS, while shoulder and elbow flexion postures were both significantly negatively associated with back MSS. Shoulder flexion posture was borderline negatively associated with neck MSS ($p = 0.06$) (Table 5). Significant associations were negative suggesting that workers with less MSS had larger discrepancies.

Table 3
Means and Frequencies of demographic, MSS, workstation configuration and discrepancy variables ($n = 74$)

Variables	M ± SD or N (%)
Demographic variables	
Age	44.2 ± 12.3
Gender (Female)	69 (93.2%)
Race and Ethnicity	
White	64 (86.5%)
African American	8 (10.8%)
Asian	1 (1.4%)
Non-Hispanic	73 (98.6%)
Hand Dominance (Right)	67 (90.5%)
Job (Hrs /Week)	39.5 ± 6.7
Computer (Hrs /Day)	6.2 ± 1.3
Touch Typing (Yes)	45 (61.6%)
MSS variables	
Neck MSS	4.1 ± 2.3
Back MSS	3.5 ± 2.3
R Hand MSS	3.4 ± 2.5
L Hand MSS	2.0 ± 1.4
Discrepancy variables (cm)	
Seat/Calf	4.7 ± 4.5
Pan/Thigh	−0.5 ± 4.2
Keyboard/Elbow	2.4 ± 5.9
Monitor/Eye	−0.7 ± 6.9
Postural variables (deg)	
Neck flexion posture	42.7 ± 10.8
Shoulder flexion posture	24.2 ± 12.9
Elbow flexion posture	103.8 ± 17.8
Wrist extension posture ($n = 69$)	22.9 ± 11.3

Table 4
Pearson's correlations between posture and discrepancy variables

	Neck flexion	Shoulder flexion	Elbow flexion	Wrist extension
Seat/Calf	−0.16	0.04	0.17	0.22
Pan/Thigh	0.06	0.02	−0.02	−0.16
Armrest/Elbow	0.06	−0.05	0.03	−0.11
Keyboard/Elbow	0.07	0.37*	−0.25†	−0.36*
Monitor/Eye	−0.22	0.10	−0.01	−0.12

†$p < 0.05$; *$p < 0.01$.

5. Discussion

Our sample was a convenience sample composed primarily of managers and staff from a large university whose primary job involved using a computer. These job titles are generally staffed by females, thus explaining the preponderance of females in this study. The anthropometrics of the study sample were similar to those of the general population [28] as indicated in Table 1. MSS symptoms were higher than those reported by other studies on computer workstations using this instrument [23]; however, our subjects were selected because they had at least a 2 level pain, while the subjects in that study were not.

Table 5
Spearman's rho correlations between MSS and discrepancy or posture variables

	Neck MSS	Back MSS	RUE MSS	LUE MSS
Discrepancy				
Seat/Calf	0.05	−0.05	0.15	0.10
Pan/Thigh	0.06	0.10	0.12	0.00
Armrest/Elbow	−0.33*	0.01	−0.10	−0.02
Keyboard/Elbow	−0.10	−0.12	−0.18	−0.00
Monitor/Eye	−0.20	−0.12	−0.25†	−0.24†
Posture				
Neck Flexion	−0.07	0.04	−0.23†	0.10
Shoulder Flexion	−0.22	−0.34*	−0.05	−0.07
Elbow Flexion	−0.09	−0.24†	−0.03	−0.09
Wrist Extension	0.01	−0.10	−0.02	−0.00

†$p < 0.05$; *$p < 0.01$.

As can be seen on Table 4, only keyboard/elbow discrepancy had a significant moderate association with postural variables. The results suggest that the higher the keyboard in relation to the seated elbow height the greater the shoulder and elbow flexion angles (smaller numbers indicate greater elbow flexion) and the smaller the wrist extension angle. Thus, the position of the keyboard has the greatest effect on the position of the shoulder, elbow and wrists. No other workplace discrepancy had a significant association with posture, although the association between monitor height and neck flexion angle, and seat pan height and wrist extension were also moderate, though they did not achieve significance ($p =$ 0.06 and 0.07 respectively). From this study it appears that the relationship of the keyboard height to the elbow height plays an important role in computer workstation postures. These results provide only limited support to the linear model that workstation discrepancies lead to awkward postures, which, in turn, may lead to MSS. One possible explanation is that while posture may be influenced by workstation set-up, personal capabilities such as underlying strength or range of motion constrain postures as well. Posture, then, may not provide the best marker of workstation/worker mismatch.

Current practice recommends that practitioners observe computer workers one time in their workstation, identify awkward postures, determine if there are discrepancies in the set-up of the workstation that could be causing the awkward postures, and adjust the workstation to reduce these discrepancies. Online sites, such as the Occupational Safety and Health Administration (OSHA) Computer Workstations [8], provide workers with information on the "best" postures to assume to influence musculoskeletal comfort. The underlying theory behind this practice is that the discrepancies in workstation set-up are one aggravating factor in the devel-

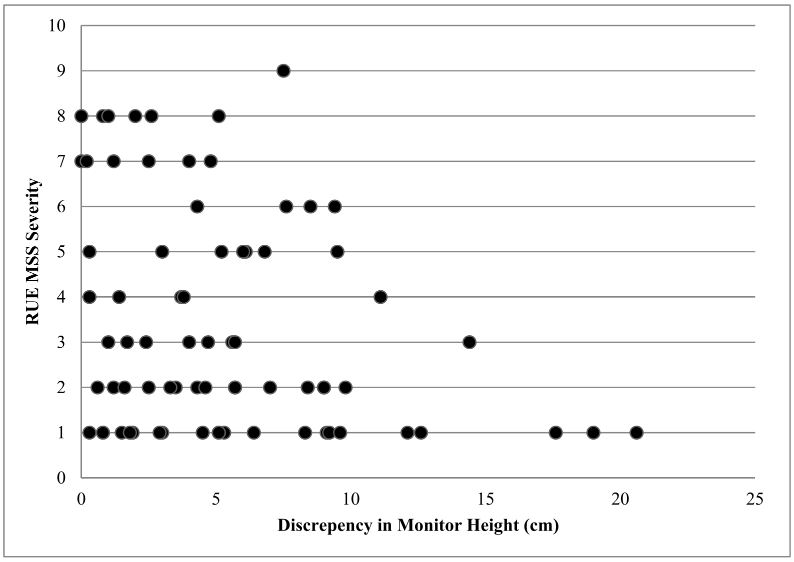

Fig. 1. Chart of the association between right upper extremity (RUE) musculoskeletal symptoms (MSS) and the discrepancy between the seated eye height and the monitor height.

opment of MSS and that changing them will reduce the MSS. The results of this study only minimally support this practice. A single recorded session of workers using their computer workstation did not find significant positive associations between MSS and discrepancies or postures. Rather, the significant associations found in this study were negative, which suggests that workers with smaller discrepancies and less awkward postures had more severe MSS. Figure 1 provides a chart visually depicting the association between RUE MSS and discrepancies between the monitor height and the seated eye height, which exemplifies the association seen in this study.

These results would be misleading if the correlations were interpreted as causal. This study was a cross-sectional study of workers with existing disorders. Workers with severe chronic MSS may have already attempted to adjust their workstation to reduce discrepancies and awkward postures in an attempt to obtain relief from symptoms while workers with milder symptoms may not have felt compelled to change their workstation because they were not in severe pain. Thus, those with less MSS might have larger discrepancies.

Thus, the assumption that discrepancies affect awkward postures and thus changing discrepancies to improve posture, thereby affecting MSS may be too simplistic, particularly for people with chronic MSS. There are many reasons why a computer worker might adopt a particular posture which are only minimally affected by environmental constraints. As stated earlier, pain, one aspect of MSS, is complex with both biological and psychological components [29]. Current thinking indicates that people with chronic pain have significantly different motor activity than those without chronic pain, in particular, chronic pain may affect the ability to perform synergistic functions related to maintaining joint stability and control [30]. Computer workers may position their computers to provide the stability that is needed to function rather than position to obtain non-awkward postures. Chronic pain also affects sensory motor interactions: people with chronic pain may not be able to accurately identify their postures [31]. Research suggests that workers with MSS may unconsciously change the way they move to guard against movements they perceive as potentially aggravating pain [32]. Workers with MSS may adopt postures to place less stress on these areas at the cost of awkward postures elsewhere. Workstations that are adjusted to match anthropometrics may actually place more stress on tissues shortened by disuse, so the worker could feel more pain initially with a "correctly" adjusted set-up or in a non-awkward posture. One other possible interpretation of these results is that not all computer operators respond to discrepancies by altering the posture of the body part most directly involved. Workers may adopt postures that improve efficiency. It is possible that if 90 degrees of elbow flexion is the most efficient position to work in, workers may respond to discrepancies in keyboard height by making more proximal postural adjustments such as repositioning the spine to maintain 90 degrees of elbow flexion.

The study reported here suggests that relying on only adjusting postures with those with chronic MSS related to computer use may not fully reduce chronic MSS. It underlines the multifactorial nature of MSS, and should encourage practitioners to think holistically as they address the needs of computer operators with chronic MSS. This study also sheds light on the conflicting results of studies which examined the effect of postural changes in computer workstations on MSS [11,13,15–17]. Studies which relied on "correct" postures without taking into account discrepancies and workers' perceptions of their MSS may have not taken into account the multifactorial nature of chronic pain and therefore may not have appeared successful.

5.1. Limitations

This study is cross-sectional and it therefore cannot identify which came first, discrepancies or MSS, so all associations have to be interpreted with this in mind. Measuring anthropometrics can be prone to error [19] so the degree of discrepancy may be over or underestimated. However, since our samples anthropometrics was similar to population anthropometrics, it is likely our error was small. Subjects' MSS was measured at only one time point, and MSS, particularly chronic MSS, tends to fluctuate. We would probably have had better results with multiple measurements. Additionally, this was a relatively small sample of subjects. A larger sample would have allowed greater power to detect differences.

6. Conclusion

Identifying if a workstation requires adaptation is more complex than looking at postures alone. It seems advisable to use a multi-modal method of determining methods to reduce MSS in computer operators. Considering the inherent assumption that worker/workstation discrepancies are the underlying cause of risky postures, it is surprising how little research has examined the association between computer operator/computer workstation configuration discrepancies and chronic MSS. Continued research is necessary to better understand the relationship between posture, discrepancies and chronic MSS, and the best method to reduce them to improve computer workstation comfort.

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