Musculoskeletal pain prevalence in randomly sampled university employees: Age and gender effects

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S.J. Weaver, N. Charness, K. Dijkstra, T. Jastrzembski. Musculoskeletal pain prevalence in randomly sampled university employees: Age and gender effects. Gerontechnology 2008; 7(3):279-292. Facets of computer workstation design were investigated in a random sample of 206 university employees, half age 50+ and half age 40 or below. Results indicated significant age effects on self-reported wrist pain, with greater pain in younger adults [Odds Ratio=2.33]. Age effects remained significant when adjusting for posture, ergonomic design, and hours at the workstation. Arm or shoulder pain showed significant gender effects, with women reporting greater intensity. Our study indicates a need to mitigate the risk of musculoskeletal disorder development in younger workers and to investigate effects of long-term workplace computer use.

Keywords: age, musculoskeletal, pain, gender, university, work

Increased usage of computer technology within the workplace over the past 10 years has corresponded with increasing reports of employment-related musculoskeletal disorders of the upper extremities[1]. In 2004, upper extremity illnesses encompassed 32% of all work-related illness resulting in time away from work in the United States[2]. An increase in this number is likely if individuals, who experienced musculoskeletal pain below current clinical diagnosis thresholds, were also included[3].

Most age groups saw a decrease in the number of work-related musculoskeletal disorders (WRMSD) reported in 2004, however, reports for workers age 55 or older remained relatively unchanged[2]. Workers over the age of 65 reported a 25% increase between 2003 and 2004 in median days away from work due to WRMSDs. This translates into a mean of 20 days absence from work for older workers suffering with WRMSDs. When considering all age groups, injury due to repetitive tasks such as typing result in the longest work absences (a median of 20 days missed)[2]. The National Academy of Sciences[4] additionally reports that $45 to $54 billion dollars are lost annually due to work-related musculoskeletal pain and disorders. Studies of musculoskeletal pain experienced by aging computer users are relatively sparse, given explosive growth of computer technology in the global workforce. Determining the impact of individual factors, such as age and gender, and physical factors, such as posture and workstation ergonomics, are vital to the development of effective and efficient WRMSD prevention programs and interventions. The health of employees, especially those who are older, has a significant impact on employer's net economic gain[5,6]. Thus there is additional incentive to create computer workstations, which are as comfortable and ergonomically sound as possible for their employees, in order to limit the financial impact of WRMSDs. Though there has been extensive empirical work to determine the ideal ergonomic design of computer workstations our understanding of the role of individual difference factors, such as age, gender, and posture is not well developed. The purpose of the current study was to compare ratings of musculoskeletal pain between age and gender groups and to investigate the role of both posture and ergonomic design in the experience of musculoskeletal pain.

Work-related musculoskeletal disorders are characterized as work-related diseases, in which work performance significantly contributes to their development and exacerbation, however, is not the sole causal agent[7,8]. Armstrong's model of WRMSD development[7] provides a conceptual framework which integrates physiological, mechanical, individual, and psychosocial factors. Specifically, they consider the interactions of exposure (for instance, work requirements and environment), dose (for instance, actual tissue load, inflammation, and stress), response (for instance, changes in the tissue itself or metabolic reactions), and capacity (for instance, physical or psychological ability to resist destabilization due to doses, such as the physical ability to resist tissue deformation). For example, Rempel et al.[9] discuss the response of peripheral nerves to loading. They discuss how a non-neutral wrist posture (exposure) results in elevated pressure within the carpal tunnel (dose). This pressure can inhibit blood flow and nerve function (responses). The ability of the wrist tissues to recover from the inhibited blood flow and tissue pressure (capacity) determines the exposure results in damage or muscle building. Armstrong's model[7] provides a framework through which we can investigate the effects of workplace design, such as ergonomics and posture, and individual factors, such as age and gender, on WRMSD symptoms.

Workplace design: Posture and ergonomics

The postures assumed during Visual Display Unit (VDU) work affect the development of WRMSDs and their symptoms. Postural risk factors, such as wrist flexion, wrist extension, repetitive shoulder flexion, and shoulder elevation, have been linked with the occurrence of WRMSD symptoms such as wrist, shoulder, arm, and neck pain[10-13]. Straker et al.[14] laboratory study showed that upper-limb discomfort was significantly affected by posture. Though their sample was comprised of college-age participants only, at the end of a 20-minute typing exercise the 0 degree shoulder flexion posture was shown to promote better performance, less discomfort, and less fatigue than a 30 degree position. The US National Institute of Occupational Safety and Health (NIOSH) also conducted an extensive review of the epidemiological evidence for the work-relatedness of various musculoskeletal disorders and their symptoms[15]. The NIOSH reported evidence that both posture and repetition contributed to the development of shoulder and hand/wrist disorders and symptoms.

The purpose of ergonomics is to design the characteristics of the job to fit with the capabilities, dimensions, and needs of the workers in the job[16,17]. Workstation design greatly impacts the postures one can assume while working. For instance, Lassen

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et al.[18] reported strong evidence for causal effects of poor ergonomic design and posture on musculoskeletal pain in the elbow and wrist/hand regions. Ergonomic measures which were associated with pain development during their one-year follow-up measurement included: higher keying activation force (how much force is needed to depress a key when typing), higher degrees of wrist deviation during mouse use, and the use of a keyboard with the j-key higher than 3.5 cm above the table surface. By creating an ergonomically designed computer workstation, employee exposure to work-related risk factors for WRMSDs and their symptoms could be reduced. NIOSH[19] published a primer on workplace ergonomic interventions, which included a computer workstation checklist. The checklist outlines their recommendations for ergonomically designed workstations and can be used to pinpoint areas which may result in potential WRMSD problems. This checklist was utilized in the current study to assess employee posture and the ergonomic design of their workstation.

Individual factors: Age and gender

Support for the impact of individual factors such as age and gender on WRMSD development has been mixed. Prior literature shows significant age effects for older workers, specifically VDU operators. Marcus et al.[20] calculated risk of both musculoskeletal symptoms of the neck/shoulder and hand/arm regions, as well as the risk of clinically diagnosed disorder in these regions, in terms of age for their sample (N=623) of newly hired American workers. Participants were starting a job requiring at least 15 hours of computer work and had not experienced any musculoskeletal pain in the last week. Using measures taken at a one year follow-up, hazard ratios (HR) showed significantly increased risks for both symptoms and disorder in the neck/shoulder region for workers over 40 ($HR_{symptoms}$=1.79, p=0.01; $HR_{disorder}$=1.75, p=0.01). Though the HR ratio for the hand/arm region did not reach significance, older workers displayed a trend towards greater risk for pain and disorder in this area also ($HR_{symptoms}$=1.55, p=0.07; $HR_{disorder}$=1.58, p=0.13). In a similar study by Gerr et al.[21], HR for the hand/arm region did not reach significance, but older workers from their sample displayed a trend towards greater risk for pain in the hand/arm region.

With regard to gender, Punnett & Herbert[3] noted that in many cases female gender is listed as a risk factor for some WRMSDs due to increased prevalence within the general population (p 477). Recent studies have narrowed their focus, finding gender effects on musculoskeletal pain reports for workers using a computer, keyboard, or mouse over a significant portion of their work day. Karlqvist et al.[22] reported that 76% of the Swedish female VDU operators reported musculoskeletal pain compared with 51% of male employees. Additionally, women who worked more than 2 hours per work day on the computer (considered 'exposed') were found to be more likely to experience symptoms in the shoulders/neck than 'unexposed' men (Odds Ratio [OR]=5.5) and in the elbow/forearm/hand (OR=5.3).

Similarly, Jensen et al.[23] demonstrated that female computer users reported musculoskeletal pain twice as much as men in the neck, shoulder, and hand/wrist areas, and that duration of computer use (self-reported as either 0, ¼, ½, ⅔ of work day, or an entire work day) was significantly associated with neck and shoulder pain in women (OR=2.0 for full working day), but not for men (OR=1.62 for full working day). Lassen et al.[18] also reported significant gender effects at almost all points of their study when examining self-reports of pain experienced in the last 12 months. Using logistic regression, baseline associations between female gender, baseline ergonomic exposures, and pain reports resulted in a significant OR of 1.69 for

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elbow pain and 1.76 for wrist/hand pain. Associations with pain categorized as severe revealed even larger OR's of 2.77 for severe elbow pain and 2.59 for severe wrist/hand pain when considering female gender, baseline ergonomic exposures, and severe pain. At the one year follow-up gender effects remained significant.

In the context of Armstrong's[7] model, age and gender effects may reduce the capacity one has to respond to doses of musculoskeletal stress. For example, an arthritic carpal tunnel would not have the same physical and metabolic resources to aid in recovery after prolonged exposure to a non-neutral wrist position as a non-arthritic carpal tunnel[24]. The literature indicates that women are the most common sufferers of diseases such as arthritis[25]. Additionally, they often suffer more severe and aggressive forms which result in poorer outcomes[26]. Though it was initially believed that women were simply more willing than men to report pain they experience, the 2007 consensus report on pain and gender[27] indicates that the literature suggests that different pain mechanisms underlie the experience of pain in men versus women and that women may deal with different and/or additional risk factors. Furthermore, the report indicates that these small differences in pain mechanisms and risks compound to underlie increased pain morbidity in women.

Age and gender effects may be considered a manifestation of cumulative exposure. Older workers, who have been in the workforce longer than younger workers may have more cumulative, workplace exposure to risk factors for WRMSD. This must be tempered with the possibility that younger workers may spend more time out of work engaged in activities that may exacerbate musculoskeletal symptoms, such as at home computer or video game use. Buckle & Devereux's[8] review of work-related upper limb musculoskeletal disorders posits that "a causal relationship is very likely between intense and long exposure to work risk factors and the development of disorders in the [upper limb] region" (p. 212). Exposure to work-related risk factors may be exacerbated by the fact that women may perform the same computer work with different postures than their male counterparts. Karlqvist[28] found that women had higher shoulder elevation and rotation than men when working with a computer mouse and that they worked with a higher degree of electrical activity in their muscles. Similarly, Wahlström[29] reported that women worked with higher finger muscle activity than men and utilized a greater percentage of their maximal muscle capacity when pressing the mouse button. Older workers may also work with more outdated technological equipment, which has poor ergonomic design, than younger workers coming into the same work environment. If the workstations of older employees are not updated to meet current ergonomic recommendations they could be forced to assume postures which foster the development of WRMSDs[15,19]. Similar effects could occur for women if their workstations are designed based upon anthropomorphic data of men or are not adjustable.

The current study

The current investigation focuses on issues of age and gender as related to pain reported by university employees who perform computer work. Specifically, we explore the prevalence of pain reported in the arm/shoulder and wrist regions of workers 40 years and younger compared with workers 50 and over who use a computer on a daily basis. Based on previous literature it was hypothesized that older workers would report significantly higher pain intensity in both the wrist and arm/shoulder regions. We also compare pain reports of men versus women in these categories and hypothesized that gender effects would mirror previous studies of women reporting significantly higher pain intensity in both measured regions. In addition, we examine the possible contributions of posture and ergonomic design of the workstation to the pain experience, and hypothesize that those scoring lower on posture and degree of ergonomic design scales would report higher pain intensity ratings. This study contributes to the literature trying to uncover the relationships between workplace factors and individual factors in the development of WRMSDs and their symptoms. It answers calls for further endeavors to identify affected worker populations in order to direct early intervention efforts and to identify conditions under which WRMSDs may occur[29]. Additionally, this investigation is unique in its use of a random sampling technique and the use of observational methods to collect posture and ergonomic design data rather than self-reports.

Method

The current project is a secondary analysis of data collected as part of the national Center for Research and Education on Aging and Technology Enhancement (CREATE) project[31]. Portions of the observational data collected for the larger project were utilized for the current examination. The methods of administration relevant to the current analyses are described below in order to facilitate understanding of the scheme and context in which data was collected.

Sample

Participants were recruited via telephone from a randomized list of employees (faculty and staff) provided with the permission of the provost of a major Southeastern United States university. The list contained contact information for 1,420 university employees. Of these 909 were reached via telephone and asked to participate. All participants who were reached via telephone completed a short telephone prescreening, regarding their use of computers at work, age, gender, and willingness to participate. Individuals were asked to participate if they worked on a computer workstation at their campus office. Employees who did not use a computer as part of their daily work on-campus (i.e., service/maintenance and skilled craft employees) were thanked for their time and removed from the sample pool.

Participants

Of those contacted, a total of 206 agreed to participate. Participants were divided in two age ranges: half were 50 and above (n=103, Range=50-77, M=57.7, SD=5.5) and half were younger than 40 (n=103, Range=20-39, M=31.3, SD=5.0). The mean tenure for workers over age 50 was 16.3 years (SD=10.9), while the mean tenure for those aged 40 or younger was 4.4 years (SD=3.6). The gender distribution was 43.3% male (n=87) and 56.7% (n=114) female. In 5 cases gender was not declared.

Participant job class was identified as either faculty or staff based on job classifications provided by the university personnel department. To test representativeness of the sample we compared the ratio of faculty-to-staff between the university population and our sample. A 2 by 2 χ^2-analysis revealed no difference between the ratio of faculty to staff in our sample (1:2.7) and the ratio of faculty to staff in the university population (1:2.8) [$\chi^2(1, n=4837)=0.09$, $p>0.05$].

Procedure

Data were collected during a 60 minute assessment of the participant's workstation. The test protocol was conducted by a trained research assistant, who completed a standardized training regimen to ensure reliability. The portions of the workstation assessment relevant to the current investigation include an observational and self-report ergonomic checklist and questionnaire. Participants were asked to bring up a document they would typically work with on their computer and assume the usual posture they would sit at during their workday. A trained research assistant then compared the participants' setup with the US National Institute for Occupational Safety & Health (NIOSH) Tray 5-G Computer Workstation Checklist[19]. The checklist requires a trained observer to rate several ergonomic aspects as either a 1 for 'yes-complies' or 0 for 'no-does not comply' (for instance, neutral wrist position, and feet flat on floor). Several items on this checklist were collapsed to form the ergonomic design measure and posture measure utilized in our analyses.

Reliability of observer ratings was assessed via two independent assessments for two cases of the sampled workstation sites. Overall inter-rater reliability was 88% and Cohen's Kappa was calculated at κ=0.58, which was considered fair.

As part of the questionnaire, participants were asked several questions regarding the intensity of any pain experienced in the arm/shoulder and wrist regions during an average work day. On a scale of 0 (no pain) to 10 (worst pain imaginable), participants were asked to rate the amount of pain they felt in these areas on an average workday.

Ergonomic design and posture variables
To determine a rating scheme for posture and ergonomic design, we created two sub-scales from the NIOSH Tray 5-G Computer Workstation Checklist[19]; a posture scale and an ergonomic scale. The posture scale consisted of 11 questions; four items related directly to posture while in the usual typing position (for instance, horizontal thighs, neutral wrists) and seven items pertained to factors thought to influence neutrality of posture (for instance, does the chair provide lumbar support?). The resulting variable allowed the range of scores to be between 0 and 11. A score of 11 indicated that the user's posture met the current NIOSH standard for neutral posture and that their workstation was conducive to neutral postures.

The degree of ergonomic design was appraised via the ergonomic design scale created using a second subset of the NIOSH questionnaire. This scale was also comprised of 11 items, and these items pertained to the physical design of the workstation. Examples include the presence of document holders, brightness and contrast controls for the computer monitor, and satisfaction with monitor viewing distance.

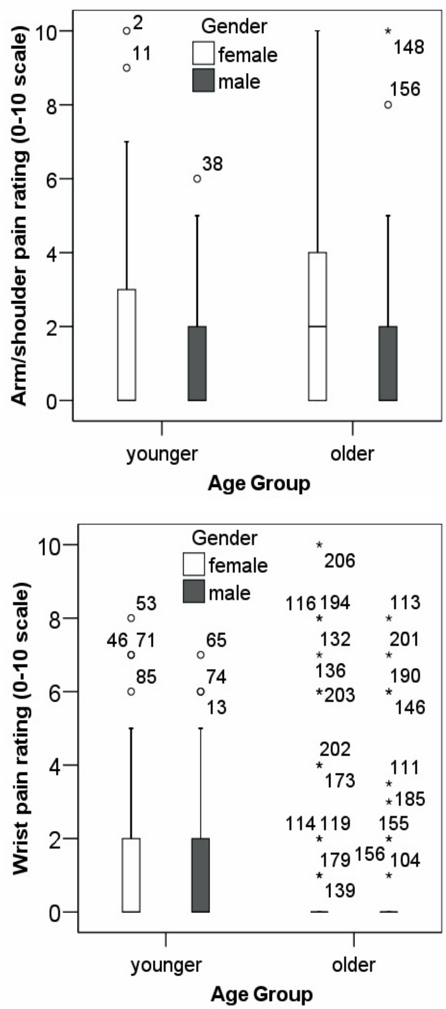

Figure 1. Distribution of arm and shoulder pain intensity, and wrist pain intensity by age group and gender; Solid lines represent the group means, while the upper and lower edges of the boxes represent the 25th and 75th quartile; Bars indicate the minimum and maximum values, while outliers (values more than 2.5 standard deviations above or below the mean) are indicated by an asterisk with the participant number. Upper: Arm and shoulder pain, lower: Wrist Pain

Similar to the posture scale, the ergonomic scale was scored on a scale of 0 to 11, with 11 indicating a very good ergonomic design according to NIOSH standards and 0 indicating the most poorly ergonomically designed workstation possible.

Age and gender variables

Age was coded as a binary variable with two levels: age 40 and below versus age 50 and above. This binary scheme was utilized in order to maximize the age comparison and the data were originally collected such that all participants fell into one of these two categories for the overarching project. The primary reason for selecting those ranges was to maximize differences in other variables such as distance from computer screen, not analyzed here. Most individuals over age 50 can be expected to be presbyopic and use corrective lenses for near vision and most individuals under the age of 40 should not be presbyopic[31].

Musculoskeletal pain variables

Self-reported pain was measured on a 0-10 scale for the wrist, and the arm/shoulder. Zero indicated no pain in the region on a usual work day and 10 the worst pain imaginable. Participants were also asked to report the number of hours per day they usually spent working on their computer. Figure 1 displays the box plots of pain intensity reported in the arm and/or shoulder (A/S) region and wrist region by age group and gender.

The solid line represents the group mean, while the edges of the box represent the 25th and 75th quartile. The bars indicate the minimum and maximum values, while outliers (values more than 2.5 standard deviations above or below the mean) are indicated by an asterisk with the participant number. Due to the skewed distribution of the pain variables, effects were assessed with non-parametric statistics.

Results

An alpha level of 0.05 was utilized for all statistical tests and a posteriori power calculations were made via G*Power[32,33] for χ^2 calculations and via SPSS 13.0 for all other calculations to enable the reader to evaluate trends.

Age, gender, duration of computer use

Table 1 presents the average age, length of employment with the university, and time per average work day spent at the computer workstation.

The average number of hours spent at the computer workstation per work day showed a relatively normal distribution. A 2-way ANOVA analysis revealed age group as a significant predictor of average hours per day at the computer workstation ($F(1, 200)=7.23$; $p=0.008$, power=0.76), as was gender ($F(1, 200)=4.18$; $p=0.04$, power=0.53). Younger workers and females reported a greater average number of hours per work day at their computer versus older workers and males. The age

Table 1. Mean age, length of university employment, and time per average work day spent at computer by age group and gender

Age & gender	n	Mean age (SD)	Mean length of employment (SD)	Mean time at workstation / day (SD)
Younger female	58	30.2 (5.03)	4.26 (3.82)	6.95 (1.48)
Younger male	45	32.6 (4.64)	4.50 (3.27)	6.63 (1.99)
Older female	61	56.9 (5.06)	15.4 (10.66)	6.45 (2.04)
Older male	42	58.5 (5.99)	17.5 (11.24)	5.67 (2.12)
Total	206	44.4 (14.16)	10.4 (10.09)	6.47 (1.95)

Table 2. Pain prevalence reported by bodily region, age, and gender

Age & gender	n	Arm or shoulder pain (rated ≥1)	Wrist pain (rated ≥1)
Younger female	58	40%	47%
Younger male	45	42%	36%
Older female	61	54%	20%
Older male	42	38%	21%
Total	206	44%	31%

group by gender interaction was not significant, however (F(1, 200)=0.73; p=0.4, power=0.14).

Age, gender, pain

Distributions of both arm/shoulder and wrist pain intensity ratings were highly skewed, with most participants reporting no pain in either region, however, 44% did report some level of arm/shoulder pain and 31% reported some level of wrist pain (*Table 2*).

Overall, young females showed the highest prevalence of wrist pain (any level of discomfort) with 47% of the sample reporting any level of discomfort. To assess the age and gender differences in pain, those experiencing moderate to severe levels of pain (ratings of 2 or higher) were compared to those experiencing no to low levels of pain (ratings of 0 and 1). Table 3 displays the percentage of participants who experienced moderate to severe pain in both regions.

χ^2 tests of independence showed a marginal relation between intensity of A/S pain and age group (χ^2 (1,n=206)=3.53, p=0.06), with older workers displaying a trend towards being slightly more likely to report A/S pain. A significant relationship was observed between wrist pain intensity and age group (χ^2 (1,n=206)=6.59, p=0.01). Younger workers were more likely (OR=2.33) to report moderate to severe wrist pain than their older counterparts.

Similar χ^2 analyses were conducted to investigate the hypothesized relation between gender and pain intensity. There was a significant association between intensity of A/S pain and gender (χ^2 (1, n=206)=3.83, p=0.05) with women more likely to report moderate to severe A/S pain than men (OR=1.8). No significant association was determined between wrist pain intensity and gender (p=0.76).

Further analysis also showed a significant interaction for wrist pain intensity level by age group and gender with younger females being more likely to report moderate to severe wrist pain than any other

*Table 3. Contingency table displaying the relation between arm/shoulder pain intensity, wrist pain intensity, age, and gender; Age group: A/S: $\chi2$=3.53 (p=.06, Φ =.131, CI [0.001, 5.02]); Wrist: $\chi2$=6.59 (p=.01, Φ = .179, CI [0.001, 5.02]); Gender: A/S: $\chi2$= 3.83 (p=.05, Φ = .136, CI [0.001, 5.02]); Wrist: $\chi2$= .097 (p=.76); Age group x gender: A/S: Age group*female gender: $\chi2$= 3.98 (p=.05, Φ = .18, CI [0.001, 5.02]); Age group*male gender: $\chi2$= .2 (p=.67) Wrist: Age group*female gender: $\chi2$= 6.06 (p=.01, Φ = .226, CI [0.001, 5.02]); Age group*male gender: $\chi2$= 1.15 (p=.28)*

Age	Arm / Shoulder: Moderate / severe		Wrist: Moderate / severe	
	Female	Male	Female	Male
Younger	33% (n=58)	28% (n=45)	36% (n=58)	29% (n=45)
Older	51% (n=61)	31% (n=42)	16% (n=61)	19% (n=42)

age/gender group (χ^2 (1, n=206)=6.06, p=0.01). No significant interaction was observed for age group and male gender in terms of wrist pain intensity (p=0.28). For A/S pain a significant interaction was observed for age group and female gender, with older females being more likely to report moderate to severe A/S pain (χ^2 (1, n=206)=3.98, p=0.05). No significant interaction was observed for age group, male gender, and A/S pain (p=0.67). Table 5 also shows the interaction of age group and gender in terms of A/S pain.

Posture scores were highly skewed, violating the parametric assumption of normality necessary for ANOVA. Therefore, the posture scale variable was dichotomized based upon the distribution of scores; high risk posture (scores at or below 7 out of 11 item scale) and low risk posture (scores of 8 and above). A logistic regression analysis in which posture scores were regressed onto age group and gender indicated that neither age group (p=0.32) nor gender (p=0.19), were significantly associated with posture ratings. A second logistic regression analysis in which wrist pain scores were regressed onto posture, age group, and their interaction term revealed that posture was not a significant predictor of wrist pain (p=0.75). The interaction term was also not significant (p=0.89). Similar analyses, in which A/S pain was regressed onto posture, age group, and their interaction term indicated no significant relationship between posture and A/S pain (p=.78) and no significant interaction (p=0.65).

The degree of ergonomic design ratings fell in a range from 7 to 11, with no one scoring a rating lower than 7, a score which indicates a majority of items met the NIOSH standard for recommended posture (M=9.6, SD=0.8). Within this range, however, ergonomic design fit the parametric assumption of normality, therefore a two-way ANOVA analysis was conducted. It revealed that neither age group (p=0.83) nor gender (p=0.3), nor their interaction (p=0.96) were significant predictors of ergonomic design ratings. It was hypothesized that degree of ergonomic design may predict pain intensity ratings in both the A/S and wrist regions. ANOVA analyses showed, however, that degree of ergonomic design was not a significant predictor of A/S pain (p=0.28), nor of wrist pain (p=0.50).

Discussion

Overall, our results are striking in that of the eight age/gender combinations in five of them nearly one out of three workers was experiencing moderate to severe musculoskeletal pain, despite their workstations being relatively ergonomically sound. Specifically, the results indicate that younger workers, regardless of gender, were significantly more likely to report moderate to severe wrist pain. This was contrary to initial hypotheses. Specifically, younger women were the group most likely to report moderate to severe wrist pain. Though not significant, there was a trend that older workers were only marginally more likely to report moderate to severe pain in the A/S region, with 51% of older women reporting moderate to severe A/S pain. Women were also more prone to reporting moderate to severe A/S pain than men. Additionally, neither posture nor ergonomic design ratings were significantly related to age group or gender, nor were they associated with reports of wrist or A/S pain intensity as hypothesized.

Our results support previous findings of increased prevalence of pain in the A/S region among older office workers. Though our results provided only marginally significant support for this finding this may have been due to a sample size much smaller than that utilized in previous studies (i.e., n=206 versus n=1500, for example). None of the reviewed literature presented corroboration of the link between younger age and increased pain reports found in our investigation. However, Brisson et al.[34] reported that VDU workers younger than

40 years tended to make more workstation changes after an ergonomics training program and subsequently experienced fewer musculoskeletal disorders than a comparison group of employees over 40. They hypothesized that one reason for their results was that the musculoskeletal symptoms in younger workers may be more easily reversed by ergonomic interventions. Combined with our findings showing that younger workers may be more at risk for wrist pain, future research on the effects of interventions aimed at younger workers is suggested.

The relation between gender and pain in our sample coincides with prior studies. A higher proportion of women from the study by Karlqvist et al.[22] reported more upper extremity musculoskeletal symptoms than men. Jensen et al.[23] found that working nearly 75% of a normal work day on the computer was associated with pain in the neck and shoulder regions for women and with pain in the hands for men. Overall, however, women from this sample reported musculoskeletal symptoms twice as often as men for all regions surveyed.

Contrary to our hypotheses, results did not indicate a significant association between posture or degree of ergonomic design and pain intensity in our sample. There is support for both theories in the literature; therefore these results may be the product of limited variation in this sample for both the posture and ergonomic design variables (generally favourable ergonomic design being observed), coupled with a somewhat lower intensity of work carried out here than in call centers and banks.

The novel results of this study with younger participants reporting significantly greater risk for higher wrist pain levels may be attributed to several factors. They suggest the possibility that the day-to-day activities completed in a university environment may be different than those tasks performed by participants in previously studied work sites, perhaps involving more intense mouse use (compared to more intense keyboard use in data entry environments). A study of actual day to day activity would be useful to address this hypothesis. Further, younger adults may enter the work environment with a greater "dose" of musculoskeletal strain from other computer-related activity, such as intense participation in computer gaming. If the latter is true, then it becomes important to consider how best to prevent WRMSD disorders by intervening earlier in the lifespan: the prevention goal of gerontechnology[36].

Current results may have also varied due to the lack of a consistent, comparable measurement instrument for reporting musculoskeletal pain or discomfort. Several studies utilized visual analogue scales or Likert-type scales, asking participants to rate pain or discomfort in various bodily areas on a scale of 0 to 5 or 0 to 10. Few utilized actual clinical diagnoses of musculoskeletal disorder. Key differences existed mainly in the wording of questions. Lassen et al.[8] asked participants to rate "any pain or discomfort during the past 12 months" as well as "pain during the last seven days" as either no pain, very mild, mild, mild to moderate, moderate, and so forth (p 522). For the current study, participants were asked to rate their level of pain experienced during an average work day. Participants may have under-reported symptoms due to the use of the word 'pain' instead of a broader word such as 'discomfort' or 'soreness', words which may also have less severe negative connotations.

Older participants may have also under-reported wrist pain based on where they attributed cause of the discomfort or pain they experienced. Anecdotally, several individuals in the older age group responded along the lines of "I have soreness in my wrist, but that's not due to what I do here at work." Self-reports of arthritis show strong increases with age[37], therefore older individuals may be more likely to attribute wrist pain to co-morbid conditions such as arthritis or as simply a side effect of the aging process[38]. Thus, as with other age-associated impairments[39], it is difficult to partition pain into factors due to normal aging processes and those due to occupational exposure to hazardous working conditions. Further, we may have observed a 'healthy worker effect' in that older workers have had ample opportunity to shift to a job niche that suits their abilities and physical needs, whereas younger workers have had fewer years to find such opportunities[40].

The increased risk of moderate to severe arm/shoulder pain for women in the current sample may have been due to the utilization of work methods different than those of sampled men or differences in exposure to biomechanical stressors even when performing the same work tasks. Punnett & Herbert[3] suggested that women may experience greater muscle and tendon stress because the majority of workstations have been designed based on anthropometric data for men. Therefore, such workplaces designed according to data from men may be inherently inappropriate for the bodily dimensions of women. Additionally, women may suffer greater exposure due to dual duties at work and in the home. Berqvist et al.[40] stated that in their sample of office VDU operators, women with young children in their home reported a higher prevalence of musculoskeletal symptoms than men and women without children, after correcting for work-related exposures. Selective attrition may also have played a role in all pain reports being that those in the population who experienced truly severe work-related symptoms may have been absent from the sampling frame due to medical leave, worker's compensation time, or simply dropping out of the workforce. It is also possible that poor postures or workstation ergonomics may have existed at some point in the past which caused tissue damage. Though the posture or ergonomic design may have been remedied in response to pain, the corrections may have been insufficient to remediate the pain.

Suggested future research
Because of the difficulty of making comparisons across different studies, it seems worthwhile to develop and validate standardized measures to quantify musculoskeletal exposure and symptom experience. Additionally, studies that are longitudinal in design would provide valuable additional evidence about exposure-related factors. Though several studies have been completed with one to five year time spans, investigations with longer sampling frames are needed to provide better evidence about exposure-related factors in the development of pain. Similarly, inclusion of a multi-cohort design within a longitudinal context that assesses daily time at workstation and reported pain could shed more light on the long-term effects of intensity of use.

Interventions utilizing ergonomics training and forearm support have shown positive results[42]. In follow-up to the current study, feedback regarding areas of both postural and work station design was provided to all participants. A one-year follow-up study is being analyzed.

Uncovering the impact of WRMSD in both older and younger workers has significant implications for training development. A review by Yeatts et al.[43] cites that adaptation of older workers to the changing work environment can be facilitated through training, especially with regard to technological changes. Our results indicate that this type of training may also be beneficial to younger workers and foster more positive musculoskeletal outcomes later in life.

Conclusions
While much of the focus in ergonomic design research recently has been on the ag-

ing workforce, our results indicate that additional attention must be paid to younger employees. Prevention is a key element in minimizing risk of musculoskeletal disorders. By reducing exposure, costs due to work-related injury and excessive health-care utilization may be managed and possibly reduced.

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