Gender Based Influences on Seated Postural Responses

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Executive Summary

The following report presents data collected from 16 subjects (8 males, 8 females) and compares the physiological responses to four different seating configurations for 45 minute sessions of simulated office work. Three different office tasks were examined during each of the four test sessions (mousing, typing, and a combination of the two). The primary focus of the study was to assess gender differences in sitting postural responses. Secondary effects due to chair or task factors were only considered if they influenced the two genders differently. All data were monitored for the entire 45 minute test session and the results presented are for this entire data set and not representative postures sampled at discrete intervals.

The data show differences between the two genders in postural alignment and seating position on the chair. The continuous spine and pelvis measures taken throughout the duration of the test sessions revealed that the females sat with a more anteriorly rotated pelvis, less lumbar flexion, and very little trunk flexion. Conversely males sat with a posteriorly rotated pelvis, greater lumbar flexion and more forward leaning trunk postures. These differences in spine postures were significant between the two genders regardless of the task performed or chair used.

The location of the individual on the chair seat pan also exhibited gender based differences depending on the chair used. These responses were most marked for the pivoting office chair with a back rest. The average locations of both the upper body centre of mass (CoM) and the hip joint were located posterior to the base of the chair for male participants and anterior to the base for female participants. Furthermore, females sat with their upper body CoM closer to the seat pan centre of pressure (CoP) than males.

The seat pan pressure profiles of a typical female and a typical male demonstrated that females exhibit a more focal area of peak pressure versus the more diffuse pressure seen in the male profile. Also, the peak pressure was located farther behind the CoP for males as compared to females. These pressure profiles support the observations of a more slouched posture and posterior rotation of the pelvis adopted by the male participants as compared to the female participants.

The task that was performed had an effect on body positioning but this was primarily consistent across gender.

Overall, the results confirm that women adopted a different postural alignment than men, specifically when examining spine and pelvis postures, when performing seated office work. Women also positioned their bodies in a different location relative to the pivot point when sitting on a chair with a back rest. This is evident in the differences in centre of mass placement as well as the location of the hip joint with respect to the pivot point of a chair. Taken as a whole, these findings suggest that men tended to slouch against the back rest while females perched closer to the front of the seat pan.

Given that there are gender differences in the way an individual positions the body over the base of an office chair, a range of motion about the pivot point should be considered. The location of the hip joint is likely a more stable measure of sitting position (and is the basis for H-Point seat design criteria in the automotive industry). To position the hip joint location directly above a pivot point would require accommodating both gender and inter-individual differences seen in the study. To accommodate 90% of the subjects a range of motion about the pivot point of approximately ±5cm would be required.

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Figure 1: Study Design – During each testing session, participants completed three tasks (mousing, typing, or combination) that were presented in random order. Ratings of perceived discomfort (RPD) were taken at the beginning, middle and end of each of the three tasks.

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Postural Alignment (Spinal Angles)

Figure 2: Gender differences seen in the lumbar, trunk and pelvis angles. Lumbar and trunk angles are shown as a percentage of maximum standing flexion (positive values represent flexion; negative values represent extension). Pelvis angle is shown as the number of degrees of deviation from vertical (positive values represent posterior tilt; negative values represent anterior tilt).

Body Position On Chair

Figure 3: Gender differences seen in the centre of mass of the head, arms and trunk (HAT CoM) and the base of the chair. Positive values indicate that the HAT CoM is in front of the base of the chair; negative values indicate that the HAT CoM is behind the base.

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Figure 8: Gender differences and individual variability of the upper body centre of mass location relative to the base point. The data represents 90% of the sampled group. Zero on the X-axis is the base of chair location.

REFERENCES

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Figure A1: The four chairs used in the study. A) fixed chair seat pan with no back; B) a pivoting chair seat pan; C) a pivoting chair with back rest; D) the spring based stool.

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Figure A4: Sample Photos illustrating computer, instrumentation setup, and marker configuration.

Figure A5: These photographs illustrate the differences in postural alignment documented between genders. Females (A) sat with more anterior rotation of the pelvis, less lumbar flexion, and very little trunk flexion, whereas males (B) had a posteriorly rotated pelvis, great lumbar flexion and more forward leaning trunk postures. (C) Represents a figure of the neutral curvatures of the spine.

Figure A6: Sample Photos illustrating trends in female (A) and male (B) pressure distribution on the stool. Note the more focal pressure distribution under the female ischial tuberosities compared to the more diffuse posterior pressure on the ischial tuberosities and posterior aspect of the ischium.
Introduction

Prolonged sitting has become an increasingly common component of the modern-day workplace. An extensive amount of research has attempted to determine the “optimal” seating position for the human spine that would reduce the risk of low back pain. Thus, different chair designs have emerged in order to allow the individual to assume an optimal seated posture while maintaining comfort and functionality of the chair. However, individuals may respond differently to different chair designs and the factors that influence these sitting behaviours are not well understood.

There is very little information in the scientific literature regarding the observation and documentation of gender differences in seated postures. While investigating which factors determine lumbar spine posture in sitting, Bridger et al. (1992) noted that when moving from a standing to a sitting posture, males have a greater loss of lumbar lordosis than females. Although their study examined a substantial number of both male and female participants (n = 25 for each gender), they did not extensively compare nor emphasize any of the gender differences observed. In a study conducted in our own laboratory examining the difference between sitting on a stability ball and on an office chair, females exhibited less lumbar flexion than males on both the chair and the ball (Gregory et al, 2004). Females also tended to exhibit more postural static responses than males. Furthermore, males and females have been found to respond differently over time when exposed to 2 hours of prolonged sitting (Beach et al, 2004). For males, the passive structures in the spine (e.g., spinal ligaments, and intervertebral discs) became stiffer during the 2 hour period. Females showed changes in passive stiffness; however these changes were not consistent across female participants. Nevertheless, there is evidence that males and females respond differently while sitting.

To our knowledge, gender differences have not been taken into account when examining different configurations of office chairs. The primary purpose of this project was to test the influence of gender on the response to different seated postural conditions. Particular focus was placed on the relative location of a chair’s pivot point and an individual’s selected seating position with measurements of the participant’s centre of mass, spine postures and pelvic position.

Definitions (From Winter, 1995)

Centre of Mass (CoM): a point equivalent to the total body mass and is the weighted average of the centre of mass of each body segment.

Centre of Pressure (CoP): a point on the support surface (seat pan) that represents a weighted average of all the pressures over the surface of the area in contact with the seat pan.

Methods

A total of sixteen participants, 8 males (mean age = 24.8 ± 1.5 years; mean height = 1.81 ± 0.06 m; mean mass = 84.6 ± 11.2 kg) and 8 females (mean age = 23.4 ± 2.1 years; mean height = 1.71 ± 0.08 m; mean mass = 66.5 ± 12.9 kg), were recruited from the university population. This population was deemed to be relevant to this study as university students tend to spend a large amount of time performing seated work. All participants were free of low back pain for 12 months prior to the testing period. The study protocol received approval from the University Office of Research and subjects gave informed consent before testing began.

Participants were required to attend four testing sessions on different days, at the same time of day for each individual. Four different office chair configurations were randomly tested and included: 1) a fixed chair with no back rest, 2) a pivoting chair with no back rest, 3) a pivoting chair with a back rest and 4) a freely pivoting spring-post stool (Appendix A, Figure A1 – photos of all 4 chairs). During each testing session, participants performed three 15-minute intervals of simulated office work consisting of a mousing task, a typing task and task involving a combination of the two activities (Figure 1). The tasks were standardized between subjects and presented in a random order to ensure that any observed differences were not attributable to the type of task performed. Participants were asked to stand up and move around after each 15-minute interval in order to assess the repeatability of repositioning the body on the chair. Prior to the 45-minute sitting period, an upright standing trial was collected for baseline measurements. Three maximum forward flexion trials were also collected before the 45-minute sitting period and the resulting maximum angles were averaged and used to normalize spinal angles. Three maximum forward flexion trials were collected after the 45-minute sitting period to compare with the pre-sitting trials.

![Figure 1: Study Design – During each testing session, participants completed three tasks (mousing, typing, or combination) that were presented in random order. Ratings of perceived discomfort (RPD) were taken at the beginning, middle and end of each of the three tasks.](image-url)
Ratings of perceived discomfort (RPD), using a 10 cm visual analogue scale (Appendix A, Figure A2), were taken during each session in order to obtain a relative measure of subjective discomfort for the four seating configurations. Measures were taken at the beginning, middle and end of each of the three tasks performed for a total of nine RPDs per session (Figure 1).

Kinematics were recorded using an optoelectronic motion analysis system (Optotrak Certus, Northern Digital Inc., Waterloo, ON) at a sampling frequency of 30 Hz for the entire 45 minute test session. Markers were placed on the chair being tested and over the following anatomical landmarks on the right side of the participant’s body: hand, wrist, elbow, shoulder, ear canal, C7/T1, T12/L1, sacrum, greater trochanter (hip), knee and ankle. Thoracic and lumbar spine angles were calculated as the angle between adjacent segments and the pelvic angle was calculated as a deviation of the pelvis from vertical. Upper body centre of mass (CoM) was calculated using anthropometric properties summarized by Winter (1990) with modifications for the trunk based on computed tomography data (Pearsall, Reid and Livingston, 1996).

Seat pan interface pressure was measured using a pressure mapping device (X2 Seating System, XSensor Technology Corporation, Calgary, AB) and continuously sampled at 5 Hz throughout each 15-minute interval. The seat pressure profile was used to obtain the locations of the centre of pressure (CoP) and peak pressure over time.

A calibration procedure was performed in order to locate the pressure mat on the chair in the global co-ordinate system. Briefly, a point located on the pressure mat at the front edge of the chair was digitized (i.e. global x and y co-ordinates were determined) and this point was located with respect to a marker fixed on the seat pan. Since the distance between these two points remained fixed, the front edge of the chair (FEC) point could be tracked regardless of the movement of the chair in space. Using the dimensions of the pressure mat cells, the location of the CoP could also be determined with respect to the FEC point. Finally, participants were asked to pivot the chair as far forwards and backwards as possible. Two markers were fixed to the underside of the seat pan and the maximum displacements were used to calculate the pivot point of the chair using the Reuleaux method (Zatiorsky, 1998).

Twenty variables were calculated for each 15-minute interval. Centre of pressure and peak pressure were expressed with respect to each other as well as the front edge of the chair (FEC), the pivot point/base of the chair and the upper body CoM. In order to analyze where the individual was sitting on the chair, the hip joint was expressed with respect to the FEC, the pivot point/base and CoM! Leg lengths were also calculated and the percentage of the thigh resting on the chair was determined.

All variables, including spine angles, were averaged over the 15 minute intervals and these values were used in the analyses since the time series were stable and the co-efficients of variation were generally below 20%, indicating results that were very consistent.

Three-way (gender*chair*task) repeated measures analyses of variance (ANOVA) with two repeated factors (chair and task) nested within gender were performed on all variables to determine if there were any significant differences between genders. Effects due to chair or task factors were only considered if they influenced the two genders differently.

**Results**

**Postural Alignment (Spinal Angles)**

The data show significant differences between genders in postural alignment regardless of the task performed or chair used. The average spine and pelvis measures revealed that female participants sat with more anterior rotation of the pelvis, less lumbar flexion, and very little trunk flexion (Figure 2). Conversely, males sat with a posteriorly rotated pelvis, greater lumbar flexion and more forward leaning trunk postures (see Appendix A, Figure A5).
Body Position on Chair

The location of the individual on the chair seat pan also exhibited gender-based differences depending on the chair used. These responses were most marked for the pivoting office chair with a back rest. Analysis of the average location of CoM relative to the pivot point revealed that males' CoM was 1.1 cm posterior and females' CoM was 4.6 cm anterior to the pivot point of the chair when a back rest is present (p = 0.0003) (Figure 3). Additionally, the hip joint was located 2.4 cm posterior to the pivot point for male participants and 2.4 cm anterior for female participants (p = 0.0039) (Figure 4).

Pressure Measurements

The seat pan pressure measurements also revealed that males and females responded differently to the pivoting office chair with a back rest. The upper body centre of mass (CoM) for males was located more posterior relative to the seat pan centre of pressure (CoP) than females (p = 0.0012) (Figure 5). In other words, females sat with their CoM closer (within 2 cm on average) to the seat pan CoP than males. The peak pressure that corresponded to the higher pressure under the ischial tuberosities of the pelvis tended to be farther behind the centre of pressure for male participants than for female participants sitting in the chair with a back rest (Figure 6), although the differences were not statistically significant. The seat pan pressure profiles of a typical female and a typical male demonstrate that females exhibit a more focal area of peak pressure versus the more diffuse pressure seen in the male profile (Appendix A, Figure A6). These pressure profiles support the observations of a more slouched posture and posterior rotation of the pelvis adopted by the male participants as compared to the female participants.
Discussion

Overall, the results confirm that women adopted a different postural alignment, specifically when examining spine and pelvis postures, than men when performing seated office work. Women also positioned their bodies in a different location relative to the pivot point when sitting on a chair with a back rest. This is evident in the differences in centre of mass placement as well as the location of the hip joint with respect to the pivot point of a chair. Taken as a whole, these findings suggest that men tended to slouch against the back rest while females perched closer to the front of the seat pan.

A further anatomical difference between men and women was observed when moving from a standing to a sitting position. For both genders, the pelvis rotated backwards from upright standing to accommodate a seated posture. Women had pelvic angles that were more anteriorly rotated in upright standing; however, males had a greater deviation from upright standing to sitting than females. This accommodation is likely one of the major influences that led to males having a more flexed lumbar spine.

Maintaining spine postures near neutral alignment, avoiding excessive spine flexion, and minimizing joint loading by adopting an upright posture are important factors in maintaining back health and preventing low back pain. Furthermore, the flexion relaxation phenomenon, where the muscles of the back shut off during spine flexion and do not help support the moment, has been found to occur in seated flexion at lumbar flexion angles ranging from 40 to 80% of maximum flexion (Callaghan and Dunk, 2002). In the current study, males adopted lumbar spine angles that were well within the range for flexion relaxation whereas female spine angles were at the lower margin of this range. Flexion relaxation has been proposed as a mechanism for low back pain during sitting, further emphasizing the importance of maintaining near neutral postures.

Although the results of this study reveal definitive differences in seated postures between genders, it is important to note that the conclusions can only be applied to the sample population that was tested. This population comprised young, healthy and active university students without any history of low back pain. Several variables may alter an individual's postural response to sitting such as age, body composition, muscular fitness and general overall fitness, occupation (i.e. amount of exposure to seated postures) and history of back pain.

Recommendations

Given that there are gender differences in the way an individual positions their body over the base point of an office chair, a range of motion about the pivot point should be considered. The spread of this data is shown in figures 7 and 8 for the hip joint and centre of mass relative to the pivot point respectively.

The figures represent approximately 90% of the individuals in the study and indicate there is a fairly large range of body positioning relative to the chair's seat post location. To position an anatomical reference location directly above a pivot point would require accommodating the differences in both gender and individuals seen in the study. The location of the hip joint is likely a more stable measure of sitting position (and is the basis for H-Point seat design criteria in the automotive industry) as it is not directly influenced by forward or backwards inclination of the trunk or arm movement as centre of mass would be.

**Hip joint** location relative to chair base for pivoting chair with back rest:
- Male Average = 2.4 cm behind base point
- Female Average = 2.4 cm in front of base point

To accommodate 90% of the subjects a range of approximately ±5 cm would be required.

**Centre of mass** location relative to chair base for pivoting chair with back rest:
- Male Average = 4.6 cm behind base point
- Female Average = 1.1 cm in front of base point

To accommodate 90% of the subjects a range of approximately ±6 cm would be required.
References


Appendix A: Supplementary Information

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