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Changes in Head and Neck Posture Using an Office Chair With and Without Lumbar Roll Support

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Study Design. A repeated measures observational study.

Objective. To investigate change in sagittal alignment of head and neck posture in response to adjustments of an office chair with and without a lumbar roll *in situ*.

Summary of Background Data. Forward head posture has been identified as a risk factor for neck pain, and there is evidence to show that ergonomic correction in sitting may reduce the incidence of pain. The effect placement of a lumbar roll has on cervical spine posture has not been previously investigated experimentally but rather, is assumed to have a positive influence on head and neck posture.

Methods. Thirty healthy male participants (18–30 years) were photographed while registered in the natural head resting position in each of 4 sitting positions with and without a lumbar roll *in situ*. Two positions incorporated adjustments to the back rest and 1 to the seat pan of the office chair. The craniovertebral (CV) angle, as a determinant of head and neck posture was measured from the set of digitized photographs obtained for each participant. Comparisons between the CV angle in all postural registrations were made using a mixed model analysis adjusted for multiple comparisons.

Results. Of the positions examined, significant differences in the mean CV angles were found with the backrest of the chair at 100° and at 110° ($P < 0.001$). With the lumbar roll *in situ* and the backrest position at 110°, there was a significant increase in the mean CV compared with the angle without the lumbar roll *in situ* (2.32°, 95% confidence interval: 1.31–3.33; $P < 0.001$).

Conclusion. The degree of angulation of the backrest support of an office chair plus the addition of lumbar roll support are the 2 most important factors to be taken into account when considering seating factors likely to favorably change head and neck postural alignment, at least in asymptomatic subjects.

Key words: head and neck posture, lumbar roll, office chair. **Spine 2010;35:E542–E548**

The posture of the head and neck and their relationship in sitting has been investigated by various occupational groups involved in workplace design.[1–6]

The forward head posture when registered in the sitting position has been identified as a risk factor for the development[7] and increased frequency and severity of neck pain.[8] Prolonged extreme forward flexion of the head and neck has been shown experimentally to produce neck discomfort[7]and radiculopathy,[9] with further consequences of loss of cervical spine extension.[8]

There is some evidence that ergonomic interventions, including that of correcting the design of the chair in the workplace, have been shown to reduce neck and shoulder pain.[10–12] Data from a number of studies on posture of the head and neck in the sitting position are available.[3,13–16] These studies provide a range of head and neck posture values under different sitting conditions in symptomatic and asymptomatic subjects and suggest that head and neck posture can be measured reliably and consistently. However, as yet there is no consensus on the optimal head and neck posture in the sitting position.

It is also accepted that all the spinal curvatures are interrelated and that head and neck posture will be adversely affected by changes lower down in the spine.[17–23] The underlying premise is that as the lumbar spine flexes, there is an accompanying change in the thoracic spine, and consequently, the head and neck assume a more protruded posture. Experimentally, there is evidence to support this view, at least in unsupported sitting, with position of the lumbar spine shown to correspondingly influence head and neck posture.[24]

The lumbar roll is a soft external lumbar support, which is designed to provide passive support to, and promote maintenance of, the natural lordotic curve when sitting.[21] The use of a lumbar roll may increase the amount of lumbar lordosis in healthy participants by tilting the pelvis anteriorly.[25,26] To date, despite the wide spread clinical use of the lumbar roll as a therapeutic intervention for postural correction of the spine,[21,22] the influence of a lumbar roll on the resting posture of the head and neck has not been investigated. Thus, the purpose of this study was to investigate whether placement of a lumbar roll while seated on an office chair influences the position of head and neck posture, more so than other typical adjustments of the chair. For this purpose, a custom-made office chair was used. The design allowed for adjustments of both back rest angle and seatpan tilt, each of which have been shown to influence the angle of lumbar lordosis.[1,19,25,27,28]

Materials and Methods

Participants

A sample of convenience comprising 30 healthy male participants was recruited for the study. Inclusion criteria were males, age range 18 to 30 years, and no history of back or neck pain. Participants were excluded on the basis of any history of

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Figure 1. The custom-made experimental chair featuring adjustable seat pan and backrest with a gravity-dependent goniometer attached. Seat height was adjustable to ensure consistent hip and knee angulation across participants.

craniofacial, cervical, shoulder, or low back injury or neurologic disease. Approval to undertake the study was granted by the local Human Ethics Committee.

Procedure

Anthropometric data comprising age (years), weight (kg), and standing height (cm) were collected from each participant. Baseline measurements of lumbar and cervical flexion and extension were taken to establish that the participants' spinal movements were within the respective normative ranges.[29,30] Lumbar spine measurements were obtained using the Modified Schober Index (cm),[31] and for the cervical spine, a Cervical Range of Motion (CROM) device (degrees) was used.[30]

Surface landmarks for measurement of head and neck posture using the craniovertebral (CV) angle[14,32–35] were identified and marked by placing an adhesive reflective ball (5 mm in diameter) on the C7 spinous process and an adhesive reflective tape (5 mm square) on the midpoint of the tragus of the ear.[36,37] The L3-L4 interspace was identified and marked by palpating upward from the L5 spinous process, so as to standardize placement of the lumbar roll.

A custom-made office chair (Figure 1) was used for all recordings. Specifications for the chair are listed in Table 1. A large protractor with a free hanging pointer was attached to the backrest to ensure data were collected at each of 3 specified backrest angles (90°, 100°, and 110°) and seatpan tilt (7°). Angle calibration on the protractor was carried out using a large two-armed goniometer, following each positional change of the backrest and seatpan. The backrest shape enabled a commercially available lumbar roll (McKenzie Lumbar Roll; Backcare, New Zealand) [length (28 cm), diameter (13 cm), and foam density (28 kg/m^3)] to be positioned securely at the apex of the lumbar curve (L3-L4 level).[1,19,25,26,38,39] A permanent marker on the lumbar roll served to ensure it was consistently placed at the L3–L4 level identified on each participant. Measurements were recorded in a single session for a total of 8 experimental sitting positions (Table 2). The order for sitting positions for each participant was randomized using a number generator.

Table 1. Design Specifications of the Custom-Made Office Chair

Components	Design Specifications
Seat pan	Level wooden base (450 mm wide × 400 mm deep) with 25-mm thick firm foam, upholstered.
Chair height	Gas lift with height adjustment (470–670 mm) above floor level.
Backrest	Flat wooden backrest (400 mm wide × 450 high) with 25-mm firm foam, upholstered, independently adjustable to incline from 80° to 110°.
Seat tilt	Independently adjustable to tilt backward from horizontal ~7°, carrying the backrest with it.
Base	Five glide feet.

For each participant, sagittal photographs of the head, neck, and shoulder from the left side were taken using a 3.2 megapixel digital camera (Olympus C-740, Tokyo, Japan) fitted on a tripod located 3 m from the chair. A free hanging plumb line in view of the captured images served to define the true vertical.

The height of the office chair was adjusted to allow each participant's hips and knees to flex approximately to 90° and for their feet to rest comfortably on the floor. A standardized set of instructions was used with each seating adjustment. Care was taken to standardize the head in natural head rest position (NHP)[40–42] on each occasion. To facilitate the NHP participants were requested to flex and extend their head to determine the position of comfort and then fix their visual gaze on the same point on a poster chart located on the wall 2.4 m directly ahead.[40,41]

Measurement of the CV Angle

The CV angle is defined as the angle between the true horizontal and a line drawn from the tip of the spinous process of C7 to the mid point of the tragus of the ear.[14,32–35,43] The CV angle was measured directly from the digital photographs using the computer program NIH ImageJ 1.32 for Windows. NIH ImageJ is a public domain image processing and analysis program

Table 2. Details of the 8 Experimental Conditions for the Office Chair

Position	Details of the Ergonomic Office Chair Adjustments
1	Seat level, backrest 90°
2	Seat level, backrest inclination 100°
3	Seat level, backrest inclination 110°
4	Seat tilted backward 7°, backrest inclination 90°
5	Seat level, backrest 90°, lumbar roll *in situ*
6	Seat level, backrest inclination 100°, lumbar roll *in situ*
7	Seat level, backrest inclination 110°, lumbar roll *in situ*
8	Seat tilt backward 7°, backrest inclination 90°, lumbar roll *in situ*

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Table 3. The Mean (Standard Deviation) and Range of Craniovertebral Angles (Degrees) in Healthy Male Participants Recorded in Each of 8 Experimental Sitting Conditions (n = 30)

Sitting Positions	Mean (Standard Deviation) (Degrees)	Minimum (Degrees)	Maximum (Degrees)
1	47.65 (5.91)	35.17	56.89
2	49.63 (6.44)	33.69	61.05
3	52.90 (6.91)	41.19	64.40
4	49.23 (6.39)	34.82	61.48
5	48.98 (6.29)	37.78	61.05
6	51.29 (6.90)	35.42	66.95
7	55.22 (7.32)	41.82	69.10
8	51.11 (6.73)	38.50	63.44

and is available freely from the website: http://rsb.info.nih.gov/ij/. Each angle was automatically calculated and rounded to 2 decimal places.

Statistical Analysis

All statistical tests were performed using SPSS 14.0 (SPSS Inc., Chicago, IL) statistical software. Reliability of the measurement of CV angle was assessed using intraclass correlation coefficient values (ICC: 2.1). A linear mixed model with unstructured covariance was used to evaluate the differences between corresponding sitting positions[44] to account for the correlations because of the repeated measures design. The dependant variable was the CV angle, and the repeated measure was the experimental sitting position that incorporated a total of 16 pairwise comparisons. The significance level of alpha = 0.05 was used to determine statistical significance. A Bonferroni adjustment was made by multiplying the unadjusted *P* values for each of the pairwise comparisons to reduce the possibility of a type 1 error being made.[45] The confidence intervals (CIs) were not adjusted.[46]

■ Results

Mean (±standard deviation) anthropometric results for the 30 participants were age 21.73 ± 3.32 years; weight 77.37 ± 13.50 kg; height 178.17 ± 7.74 cm; and body mass index 24.27 ± 3.53 kg/m^2. The ICC values of 0.99 (95% CI: 0.96–1.00, $P < 0.001$) showed excellent intraobserver reliability[47] for the CV angles using the NIH ImageJ software when examined on 10 repeated measurements.

The mean (±standard deviation) and range of the CV angles for the 8 experimental conditions using adjustments to the back rest and seat pan tilt of the office chair with and without the lumbar roll *in situ* are given in Table 3. The largest significant difference between mean CV values recorded without the lumbar roll *in situ* was between that of positions 1 (backrest 90°) and 3 (backrest 110°) (5.25°, 95% CI: 4.16–6.34, $P < 0.001$) (Table 3). The largest difference between mean CV angles with the lumbar roll *in situ* was between positions 5 (backrest 90°) and 7 (backrest 110°) (6.24°, 95% CI: 4.96° to 7.53°; $P < 0.001$) (Table 3).

The results from the mixed model analysis used to compare the between mean CV angles of the sitting positions 1 to 4 (without the lumbar roll *in situ*) (Figure 2) identified a significant increase in CV angles in position 2 (backrest 100°) ($P < 0.005$) and position 3 (backrest 110°) ($P < 0.001$), when compared with position 1 (backrest 90°). The results also identified a significant increase in CV angles in position 1 (backrest 90°) ($P < 0.005$) and position 3 (backrest 110°) ($P < 0.001$), when compared with position 4 (seatpan tilt 7°). The nonsignificant finding was between sitting position 2 (backrest 100°) and sitting position 4 (seatpan tilt 7°) (0.40°, 95% CI: −1.52 to 0.74 $P = 1.00$).

The results from the mixed model analysis for the between mean CV angles for sitting positions 5 to 8 with the lumbar roll *in situ* are given in Figure 3. Here significant differences in mean CV angles were identified between position 6 (backrest 100°) and position 7 (back-

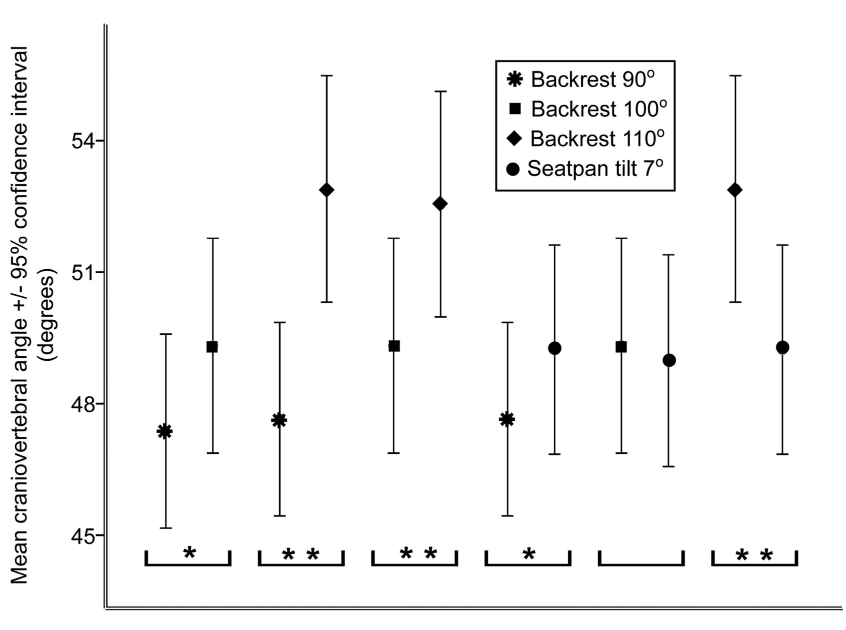

Figure 2. Pairwise comparisons (⌊⌋) between the mean (±95% confidence interval) craniovertebral angles (degrees) in healthy male participants (n = 30) recorded in sitting positions 1–4. *$P < 0.005$; **$P < 0.001$.

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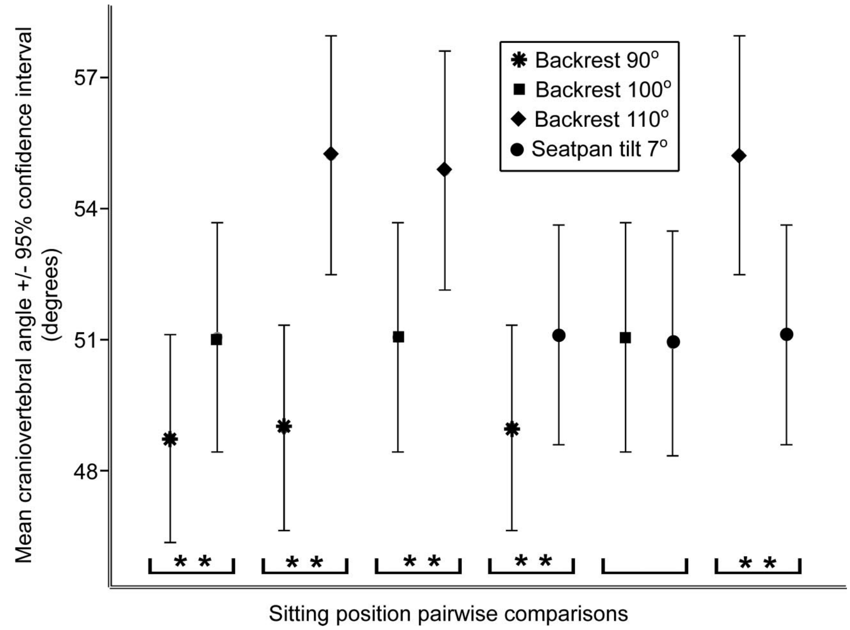

Figure 3. Pairwise comparisons (⎵) between the mean (±95% confidence interval) craniovertebral angles (degrees) in healthy male participants recorded in four experimental sitting positions with a lumbar roll *in situ* (n = 30). $^{**}P < 0.001$.

rest 110°), when compared with position 5 (backrest 90°) ($P < 0.001$). Position 5 (backrest 90°) and position 7 (backrest 110°), when compared with position 8 (seatpan tilt 7°) also showed significant differences in CV angle ($P < 0.001$). The difference between position 6 (backrest 100°) and position 8 (seatpan tilt 7°) was not significant (0.18°, 95% CI: − 1.26° to 0.90°, $P = 1.00$).

The final component of the mixed model analysis undertaken was to compare corresponding sitting positions with and without the lumbar roll *in situ*. The 1 sitting position in which a significant difference in the CV angle could be demonstrated with and without the lumbar roll *in situ* was with the backrest positioned at 110° (positions 3 and 7) (2.32°, 95% CI: 1.31–3.33; $P < 0.001$) (Figure 4).

■ Discussion

The aim of our study was to investigate the possible influence of a lumbar roll on head and neck posture as determined by the CV angle using typical ergonomic adjustments to the seatpan and backrest tilt of an office chair. Results showed that as the backrest of the office chair was reclined from 90° to 110°, there was a significant change to resting head and neck posture (Figures 2 and 3). The effect of tilting the seatpan backward, and the backrest moving with it, was essentially the same as positioning the backrest at 100°. Furthermore, the addition of a lumbar roll was only associated with a significant change in head and neck posture when the backrest of the office chair was positioned at an angle of 110°

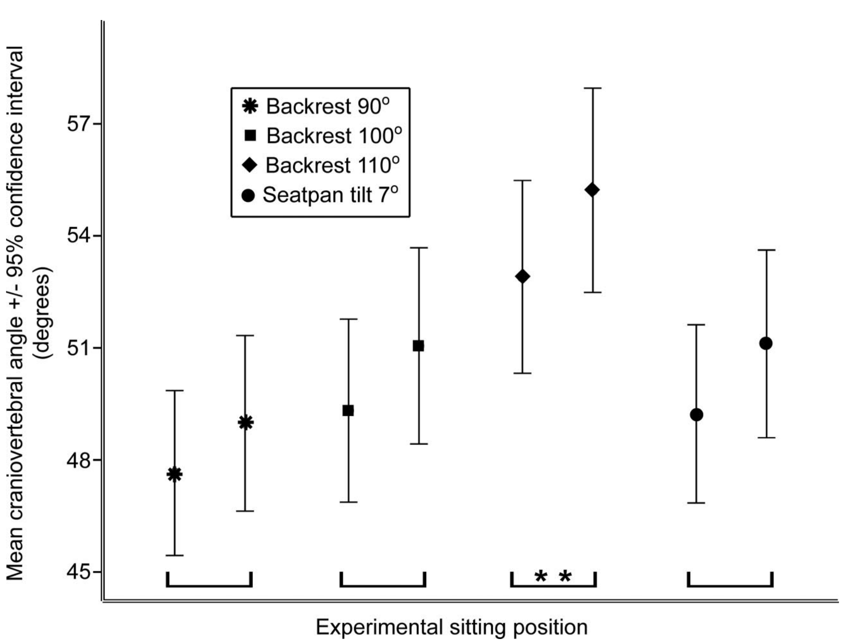

Figure 4. The mean (±95% confidence interval) craniovertebral angles (degrees) in healthy males participants recorded in four experimental sitting positions and then correspondingly, with a lumbar roll *in situ* (n = 30). $^{**}P < 0.001$.

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(Figure 4). The finding of a significant change in the CV angle when the backrest was inclined backward beyond 90° confirms previous observations of associations between chair backrest angle and sagittal plane head and neck posture.[3,48] Importantly, the finding that the forward head posture was significantly reduced with the addition of lumbar roll in an angle-specific position of 110° back rest inclination in the office chair, and not at smaller angles, has not been noted previously.

Changes in CV angle associated with the changes in neck posture were small, and hence a method of measurement that uses bony landmarks is important for accuracy. The most common method for measuring the CV angle is to use the landmarks of the C7 spinous process and the tragus of the ear, while the subject is registered in NHP, either in standing or sitting. The inter and intraexaminer reliability of measuring CV angle has been shown to be high (ICC: 0.88–0.99),[14,16,34,35] and in our study, the intraexaminer reliability was also found to be high (ICC: 0.99, 95% CI: 0.96–1.00, $P < 0.001$), thus confirming the accuracy of the method of choice.

There are a number of different types of lumbar rolls available commercially, each with different densities. The lumbar roll used in this study was selected because its technical specification was known, and the same model had been used in a study on low back pain.[39] However, given that the type of lumbar roll used by a person is dependant on their personal comfort, a limitation of our study is that the results cannot be generalized to the use of other lumbar rolls or to chairs with a fixed lumbar support.

Our study had some other limitations. First, the postural registrations provided a single frame reference of head and neck posture and as such, does not take into account possible temporal changes in posture, the effect of the demands of specific working tasks nor possible influences of work fatigue.[48,49] Results of other studies in which measurement of the temporal effect on head and neck posture with the participant performing a task, such as typing, reading, or watching a video monitor have been undertaken and have shown that shrinkage of the spine can occur over time in certain positions.[1,3,11,27,50] In particular, it must be acknowledged that in situations involving prolonged sitting, the spine may adapt to the lumbar roll *in situ* and time-related changes may occur.

A further limitation of our study is that head tilt position with reference to the orientation of the base of the skull or the occiput relative to the upper cervical segments[24] was not taken into account when measuring head and neck posture. Head tilt is known to remain relatively constant across various sitting postures because of the need to maintain a visual target at eye level,[24] and for this reason, the postural parameter of head tilt was not included in our study. However, some researchers consider that both postural parameters of head tilt and head and neck posture are independent of each other and that both measures should be used to obtain a more useful description of sagittal plane posture of the head and neck region.[51]

The thoracic kyphosis is acknowledged as an important element to be considered in determining the maximum amount of sagittal head excursion able to be measured in an individual.[34] One investigator estimated that the T6–T12 intervertebral joints may contribute up to 10% of the cervical spine movement.[52] Given that postural alignment of the head in the sagittal plane is related to the curvature of the upper thoracic spine,[34] it is reasonable to suggest that the affect demonstrated on head and neck posture associated with adjustment of the backward tilt of the chair may be attributed to the influence of kyphosis of the upper thoracic spine.

The findings from our study have implications for ergonomics and clinical practice and challenge the common clinical assumption that use of a lumbar roll by default will favorably alter head and neck posture. The effect on head and neck posture demonstrated with the large backrest angle reinforces the need for the clinician to assess individual postural responses in sitting when considering prescribing a lumbar roll for a patient to use. The results also highlight the need to standardize the details of the backrest and seatpan positions when undertaking postural assessment in the sitting position because of the potential for these variables to influence head and neck position.

Previous studies have recorded CV angles ranging from 39.0 ± 8.9° to 48.2 ± 3.2°.[16,32,36,53] The majority of these values were lower but covered a wider range than the values recorded in this study. Thus, it may be implied that standardizing the seating conditions including backrest inclination as this study did, is important for accuracy of measurements when investigating head and neck posture.

The issue of whether subtle changes in head and neck postural angles are clinically meaningful has been raised previously.[54] It is not known whether the small but significant difference observed in this study is clinically relevant. However, subtle changes in chair position have been shown to reduce abnormal spinal stress such as a forward head posture and to be associated with higher comfort ratings.[18]

The results of our study showed that reclining the backrest of a chair from an angle of 90° to 110° results in a more retracted head and neck posture for healthy subjects in the sitting position. This new information may prove to be useful from an ergonomic perspective and may be applied to facilitate improved head and neck alignment in healthy individuals who have a tendency to adopt a more forward head posture in sitting.

Clinically, patients are advised to use a lumbar roll in the sitting position to maintain the lumbar lordosis as it is purported to have a positive influence on head and neck postural alignment.[22] The results of this study indicate that the lumbar roll *in situ* had limited influence on head and neck posture when the backrest of the chair was in the more upright positions and that the back sup-

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port of the office chair needed to be posteriorly reclined to at least an angle of 100° to have a positive influence on head and neck alignment. There is little knowledge about the influence associations between chair design and head and neck posture may have on individuals presenting with spinal pain. Although our study was undertaken on healthy subjects the outcomes may be considered when making adjustments to office chairs for individuals with spinal pain.

It would also be valuable to investigate whether postural responses to ergonomic chair settings change with age. It is well accepted that the NHP assumes a more forward position with age, and thus, it may be that use of a lumbar roll is less effective with increasing age or alternatively may improve head and neck alignment in accordance with the positional adjustment of the chair.

Conclusion

The findings of our study have shown that the degree of angulation of the backrest support of a chair is an important factor to be taken into account in healthy male individuals when considering seating adjustments likely to influence head and neck posture. In this experimental situation, there was a tendency in the participants to move their head and neck into a more retracted position as the backrest of the office chair was reclined. The addition of the lumbar roll did not alter head and neck posture significantly unless the backrest of the office chair was positioned at 110°. Collectively, these results serve to highlight the importance of assessing the adjustable features of an office chair when providing postural advice on an individual's head and neck posture.

Key Points

- Significant incremental changes take place in head and neck posture as the backrest of the office chair is reclined backward.
- The addition of a lumbar roll to the office chair results in a significant change in head and neck posture when the backrest of the chair is reclined to a position of 110°.
- The combination of a lumbar roll and a posterior inclination of the backrest are the 2 ergonomic adjustments to an office chair most likely to favorably change head and neck posture in sitting at least in asymptomatic subjects.

References

1. Bendix T. Seated trunk posture at various seat inclinations, seat heights and table heights. *Hum Factors* 1984;26:695–703.
2. Bendix T, Hagberg M. Trunk posture and load on the trapezius muscle whilst sitting at sloping desks. *Ergonomics* 1984;27:873–82.
3. Burgess-Limerick R, Mon-Williams M, Coppard VL. Visual display height. *Hum Factors* 2000;42:140–50.
4. Chiu TTW, Ku WY, Lee MH, et al. A study on the prevalence of and risk factors for neck pain among university academic staff in Hong Kong. *J Occup Rehabil* 2002;12:77–91.
5. Straker L, Jones KJ, Miller J. A comparison of the postures assumed when using laptop computers and desktop computers. *Appl Ergon* 1997;28:263–8.
6. Szeto GPY, Straker L, Raine S. A field comparison of neck and shoulder postures in symptomatic and asymptomatic office workers. *Appl Ergon* 2002;33:75–84.
7. Harms-Ringdahl K. On assessment of shoulder exercise and load-elicited pain in the cervical spine. Biomechanical analysis of load—EMG—methodological studies of pain provoked by extreme position. *Scand J Rehabil Med Suppl* 1986;14:1–40.
8. Haughie LJ, Fiebert IM, Roach KE. Relationship of forward head posture and cervical backward bending to neck pain. *J Manual Manipulative Ther* 1995;3:91–7.
9. Abdulwahab SS, Sabbahi M. Neck retractions, cervical root decompression, and radicular pain. *J Orthop Sports Phys Ther* 2000;30:4–9, discussion 10–2.
10. Aaras A, Horgen G, Bjorset HH, et al. Musculoskeletal, visual and psychosocial stress in VDU operators before and after multidisciplinary ergonomic interventions. *Appl Ergon* 1998;29:335–54.
11. Bonney RA, Corlett EN. Head posture and loading of the cervical spine. *Appl Ergon* 2002;33:415–7.
12. Rempel DM, Wang P-C, Janowitz I, et al. A randomized controlled trial evaluating the effects of new task chairs on shoulder and neck pain among sewing machine operators: the Los Angeles garment study. *Spine* 2007;32:931–8.
13. Braun BL, Amundson LR. Quantitative assessment of head and shoulder posture. *Arch Phys Med Rehabil* 1989;70:322–9.
14. Dalton M. *The Effect of Age on Cervical Posture in a Normal Female Population*. Adelaide: Manipulative Therappists Association of Australia; 1989.
15. Grimmer K. The relationship between cervical resting posture and neck pain. *Physiotherapy* 1996;82:45–51.
16. Watson DH, Trott PH. Cervical headache: an investigation of natural head posture and upper cervical flexor muscle performance. *Cephalalgia* 1993;13:272–84.
17. Cyriax J. *Textbook of Orthopaedic Medicine Vol 2. Diagnosis of Soft Tissue Lesions*. 8th ed. London: Bailliere, Tindall and Cassell; 1962.
18. Harrison D, Harrison S, Croft A, et al. Sitting biomechanics part I: review of the literature. *J Manipulative Physiol Ther* 1999;22:594–609.
19. Keegan JJ. Alterations of the lumbar curve related to posture and seating. *J Bone Joint Surg Am Vol* 1953;35-A:589–603.
20. Kendall FP, McCreary EK, Provance PG. *Muscles Testing and Function*. 4th ed. Baltimore: Williams and Wilkins; 1993.
21. McKenzie RA, May S. *The Lumbar Spine: Mechanical Diagnosis and Therapy*. 2nd ed. Waikanae: Spinal Publications; 2003.
22. McKenzie RA, May S. *The Cervical and Thoracic Spine: Mechancial Diagnosis and Therapy*. 2nd ed. Waikanae: Spinal Publications; 2006.
23. Mennell J. Back Pain. *Diagnosis and Treatment Using Manipulative Techniques*. Boston: Little, Brown and Company; 1960.
24. Black KM, McClure P, Polansky M. The influence of different sitting positions on cervical and lumbar posture. *Spine* 1996;21:65–70.
25. Andersson GB, Murphy RW, Ortengren R, et al. The influence of backrest inclination and lumbar support on lumbar lordosis. *Spine* 1979;4:52–8.
26. Majeske C, Buchanan C. Quantitative description of two sitting postures. With and without a lumbar support pillow. *Phys Ther* 1984;64:1531–5.
27. Bendix T, Poulsen V, Klausen K, et al. What does a backrest actually do to the lumbar spine? *Ergonomics* 1996;39:533–42.
28. Bridger RS, Von Eisenhart-Rothe C, Henneberg M. Effects of seat slope and hip flexion on spinal angles in sitting. *Hum Factors* 1989;31:679–88.
29. Battie MC, Bigos SJ, Fisher LD, et al. The role of spinal flexibility in back pain complaints within industry. A prospective study. *Spine* 1990;15:768–73.
30. Youdas JW, Garrett TR, Suman VJ, et al. Normal range of motion of the cervical spine: an initial goniometric study. *Phys Ther* 1992;72:770–80.
31. Macrae IF, Wright V. Measurement of back movement. *Ann Rheum Dis* 1969;28:584–9.
32. Braun BL. Postural differences between asymptomatic men and women and craniofacial pain patients. *Arch Phys Med Rehabil* 1991;72:653–6.
33. Harrison AL, Barry-Greb T, Wojtowicz G. Clinical measurement of head and shoulder posture variables. *J Orthop Sports Phys Ther* 1996;23:353–61.
34. Raine S, Twomey L. Posture of the head, shoulders and thoracic spine in comfortable erect standing. *Aust J Physiother* 1994;40:25–32.
35. Raine S, Twomey LT. Head and shoulder posture variations in 160 asymptomatic women and men. *Arch Phys Med Rehabil* 1997;78:1215–23.
36. Fernandez-de-las-Penas C, Alonso-Blanco C, Cuadrado ML, et al. Forward head posture and neck mobility in chronic tension-type headache: a blinded, controlled study. *Cephalalgia* 2006;26:314–9.
37. Tully EA, Fotoohabadi MR, Galea MP. Sagittal spine and lower limb move-

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ment during sit-to-stand in healthy young subjects. *Gait Posture* 2005;22: 338–45.
38. Andersson GB, Ortengren R. Myoelectric back muscle activity during sitting. *Scand J Rehabil Med Suppl* 1974;3:73–94.
39. Williams MM, Hawley JA, McKenzie RA, et al. A comparison of the effects of two sitting postures on back and referred pain. *Spine* 1991;16:1185–91.
40. Grimmer K. An investigation of poor cervical resting posture. *Aust J Physiother* 1997;43:7–16.
41. Solow B, Sandham A. Cranio-cervical posture: a factor in the development and function of the dentofacial structures. *Eur J Orthod* 2002;24:447–56.
42. Solow B, Tallgren A. Natural head position in standing subjects. *Acta Odontol Scand* 1971;29:591–607.
43. Johnson GM. The correlation between surface measurement of head and neck posture and the anatomic position of the upper cervical vertebrae. *Spine* 1998;23:921–7.
44. Demidenko E. *Mixed Models, Theory and Applications*. 1st ed. New Jersey: Wiley Interscience; 2004.
45. Sierevelt IN, van Oldenrijk J, Poolman RW, et al. Is statistical significance clinically important?—a guide to judge the clinical relevance of study findings. *J Long-Term Effects Medical Implants* 2007;17:173–9.
46. Keppel G. *Design and Analysis: A Researcher Handbook*. 3rd ed. New Jersey: Prentice Hall; 1991.
47. Fleiss JL. *The Design and Analysis of Clinical Experiments*. 1st ed. New York: Wiley; 1986.
48. Wong TFY, Chow DHK, Holmes AD, et al. The feasibility of repositioning ability as a tool for ergonomic evaluation: effects of chair back inclination and fatigue on head repositioning. *Ergonomics* 2006;49:860–73.
49. Corlett EN. Background to sitting at work: research-based requirements for the design of work seats. *Ergonomics* 2006;49:1538–46.
50. Szeto GP, Straker LM, O'Sullivan PB. A comparison of symptomatic and asymptomatic office workers performing monotonous keyboard work—1: neck and shoulder muscle recruitment patterns. *Man Ther* 2005;10:270–80.
51. Ankrum DR, Nemeth KJ. Head and neck posture at computer workstations. What's neutral? *Proceedings of the 14th Triennial Congress of the International Ergonomics Association*. 2000:565–8.
52. Persson PR, Hirschfeld H, Nilsson-Wikmar L. Associated sagittal spinal movements in performance of head pro- and retraction in healthy women: a kinematic analysis. *Manual Ther* 2007;12:119–25.
53. Treleaven J, Jull G, Atkinson L. Cervical musculoskeletal dysfunction in post-concussional headache. [See comment]. *Cephalalgia* 1994;14:273–9, discussion 57.
54. Refshauge K. The relationship between cervicothoracic posture and the presence of pain. *J Manual Manipulative Ther* 1995;3:21–4.

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