Investigation of Spinal Curvature While Changing One's Posture During Sitting

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As sedentary, static work postures have become increasingly prevalent in our workplaces, musculoskeletal problems – in particular, low back pain and discomfort – have also increased. Researchers agree on the importance of changing one's posture while providing adequate back support. This study provides the basis for developing a backrest that accommodates natural human motion. Kinematic motion of twenty subjects were recorded in a seated position. While moving between flexion to extension, thoracic kyphosis increases and lumbar lordosis increases. Thoracic curvature changed uniformly through the full range of motion (80f-115f). Lumbar curvature changed only as the thigh-torso angle exceeded 95f. The path and rate of curvature of the lumbar spine (L3) is independent of the path and rate of curvature of the thoracic spine (T6) and is a function of the complex combined motion of pelvic rotation and variations in spinal curvature. These findings suggest that a backrest should provide independent lumbar and thoracic support to ensure that the backrest continues to support one's posture while promoting natural patterns of motion of the spine.

Introduction

Sitting is the most frequently assumed posture, approximately 75 percent of the workforce has sedentary jobs. However, prolonged static sitting is frequently accompanied by discomfort and musculoskeletal complications that result from sustained immobility (Hult, 1954; Eklund, 1967; Magora, 1972; Kelsey, 1975; Lawrence, 1977). Reinecke et al. (1985) showed a correlation between static seated postures and back discomfort concluding that individuals are better able to sit for prolonged periods when they can change their posture throughout the day.

Several researchers have evaluated the physiologic affects of changing ones posture or more directly spinal motion. Holm and Nachemson (1983), investigated the effects of various types of spinal motion on metabolic parameters of canine intervertebral discs. They suggest that the flow of nutrient-rich fluids to and from the intervertebral discs increases with spinal movement. Adams (1983) also found that alternating periods of activity and rest, thereby introducing postural change, further boosts the fluid exchange, helping to nourish the discs. Grandjean (1980) is another who maintains that alternately loading and unloading the spine (through movement) is ergonomically beneficial, because the process pumps fluid in and out of the disc, thereby improving nutritional supply.

Chaffin and Andersson (1984) have reported that the two most important considerations in seating are adequate back support and allowance for movement or postural change. Good seating should allow a worker to maintain a relaxed, but supported, posture and should allow for freedom of active motion over the course of the day. Kroemer (1994) noted that a backrest should allow for stimulation of the back and trunk muscles by moving through, and holding the back in, various postures. While freedom of movement is beneficial, extended association of muscle forces on the trunk also generates spinal compression, and a backrest can support the trunk and serve as a secondary support mechanism, thereby reducing the necessary muscle forces and reducing the compressive loading of the spinal column.

In summary, active movement and postural changes are inevitable, and in fact desirable, throughout the day. Schoberth (1962) recommends changing postures around a relaxed, upright, seated posture to minimize muscular activity and the static muscular load needed for sitting. Most researchers agree that motion should be incorporated in seating while the body is being supported in different postures.

Little information is available on spinal curvature and pelvis rotation while a person is moving in a seat. The objective of this study is to describe the kinematic movement of the upper trunk and use this information to aid designers in developing a backrest that actively accommodates natural human motion in a relaxed and unrestricted manner. The resulting backrest system should support the body, contin-uously and throughout the entire range of motion, but should not constrain natural movement. A backrest that naturally moves with a person while continuously providing support would gain from the physiologic benefits of spinal motion.

Methods

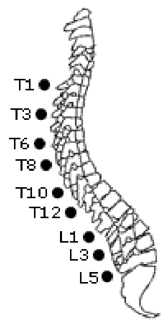
Subjects:

Twenty subjects (10 female, 10 male) participated in the study. Among the men, heights ranged from 163.2 to 188.4 cm (mean 176.2 cm) and weights ranged from 59.5 to 93.4 kg (mean 75.9 kg). Among the women, heights ranged from 144.8 to 177.8 cm (mean 165.9 cm) and weights ranged from 46.3 to 81.6 kg (mean 60.1 kg).

Procedures:

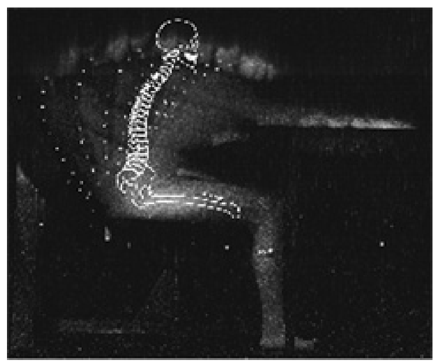
Targets, consisting of a light-emitting diode (LED) and a 1 cm calculator battery were attached to the skin over the posterior vertebral body at the following locations: Thoracic vertebrae, T1- T3 - T6 - T8 - T10 - T12, Lumbar vertebrae, L1 - L3 - L5, (Figure 1) and mid-point femur and tibia while the subjects were seated in the test fixture. The test fixture allowed subjects to move, unsupported, between a forward-flexed position (80f trunk-thigh angle) to an extended, reclined position (115) without affecting their natural motion (Figure 2). During the data collection period. Seat-pan tilt was adjusted to three positions: -5f rearward, 0f horizontal and +5f forward tilt. Positioned behind the seat pan was a fixed backrest that served as a “safety backrest.” The backrest provided confidence as a backstop at the fully reclined position. The backrest was split, with a 20-cm gap between the two lateral supports, allowing enough room so that the LED targets would not become compressed when subjects adopted a fully reclined position. Subjects were positioned and adjusted to the test fixture for seat-pan height (popliteal height) and buttock position. A removable positioning support ensured that all subjects' buttocks were positioned in the same location.

Figure 1



POSITION OF LED MARKERS ON SPINE

Figure 2



LED'S DEPICT SPINAL AND PELVIC MOTION

Seat-pan depth was 44 cm with a 2.5 cm foam pad upholstered over a flat surface. Once seated, subjects practiced moving through the full range of motion: 80? forward flexion to 115 extension. Once the subjects felt comfortable and natural with the motion, time-lapse photographs were taken at a rate of 4 frames per second. Each test position was repeated to evaluate repeatability. Subjects repeated the motion for all three seat-pan angles: +5? forward tilt, 0? degrees and -5? backward tilt.

The test procedure was repeated with a 76.2 cm work surface placed in front of the subject. Subjects' arms rested on the top of the work surface in the forward-flexed position.

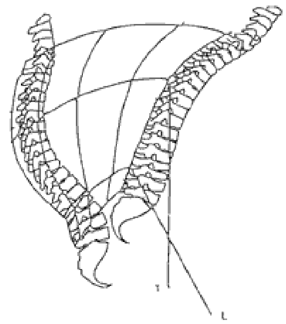
Results

Table 1

Test position		Change in kyphotic thoracic curvature		Change in lordotic lumbar curvature	
Seat-pan tilt	Worksurface	Avg.	Std.D.	Avg.	Std.D.
-5°	No	3.94°	2.31°	7.13°	5.82°
-5°	Yes	8.13°	3.79°	5.50°	2.95°
0	No	3.38°	2.63°	5.13°	4.82°
0	Yes	5.63°	3.50°	4.50°	2.65°
+5°	No	3.75°	2.02°	4.13°	3.69°
+5°	Yes	6.19°	4.47°	3.75°	2.99°

AVERAGE CHANGE IN CURVATURE FROM 80F TO 115F FORWARD FLEXION.

Figure 3



THORACIC KYPHOTIC AND LUMBAR LORDOTIC CURVATURE INCREASES AS A PERSON RECLINES

Both lumbar and thoracic curvature were measured using the National Institute for Occupational Safety and Health (NIOSH) method. Lordosis angles were determined by drawing a line connecting the points of the corresponding posterior vertebral body at L1 to L3 and L3 to L5. At the superior margins of L1 and L5, perpendicular lines were drawn so that their intersection formed the angle of lordosis at the lumbar region. Kyphosis angles were determined by drawing a line connecting the points T1 to T6 and T6 to T12. At the superior margins of T1 and T12, perpendicular lines were drawn so that their intersection formed the angle of kyphosis at the thoracic region.

The average change in thoracic curvature was 3 (S.D. 1.6) for flexion angles between 80f to 95f and 2.7f (S.D. 1.7) between 95f to 115f. The average change in lumbar curvature was .08 (S.D. 1.1) for flexion angles between 80f to 95f and 4.5f (S.D. 1.8) between 95f to 115f.

Pelvic rotation was monitored by the translation of the thigh (femur) posteriorly, as the pelvis rotates rearward about the ischial tuberosity. Quantitative data for the exact amount of pelvic rotation could not be obtained. However, qualitative assessments of the magnitude of pelvic rotation were made. The amount of pelvic rotation was observed by the distance the thigh moved rearward; the greater the distance, the greater the amount of hip rotation. The average rearward thigh translation was 5.57 cm. (S.D. 1.24)

Conclusion

Thoracic region of the spine:

1. Thoracic curvature becomes more kyphotic as the person reclines (Figure 3).
2. Variance among subjects was significant.
3. Change in curvature was consistent for the full range of motion, from 80f to 115f.
4. Seat-pan angle did not affect thoracic curvature.
5. Subjects displayed greater kyphosis when they were seated at a worksurface.

Lumbar region of the spine:

1. Lumbar curvature becomes more lordotic as the person reclines (figure 3).
2. Variance among subjects was significant.
3. Changes in curvature occurred primarily from 95f to 115f of the range of motion.
4. Seat-pan angle did not affect lumbar curvature.
5. Lumbar curvature was not affected by the presence of a worksurface.

Pelvic rotation:

1. Pelvic rotation decreased when subjects were seated at a workstation.
2. Variance among subjects was significant.
3. Seat-pan angle did not affect pelvic rotation.

Discussion

Seating design should be considered from the perspective of the end users and their postural requirements. Thus, a main objective should be to determine the ways in which a chair can support the body while, at the same time, providing for unrestricted movement. One should expect a chair to conform to, or accommodate, the body, rather than expecting the user to conform to the shape of the chair. In order to refine design criteria consistent with this expectation, this study was conducted to record kinematic motion of the back during unrestricted movement.

It was found that the motion of the upper trunk represents a combination of spinal movement and pelvic rotation. As a seated individual moves from a forward-flexed position (80f trunk-thigh angle) to a reclined position (115f), both thoracic kyphosis and lumbar lordosis increases. The path and rate of motion of the lumbar spine (L3) are independent of the path and rate of motion of the thoracic spine (T6), additionally; both parameters vary with the complex, combined motion of pelvic rotation, as well as changes in spinal curvature.

To provide maximal support, a chair's backrest should follow the motion of the back while the seated individual changes position. The backrest must, therefore, be flexible enough to provide continuous support in both an upright and reclined position. This study demonstrates the need for a backrest that can change its contouring as an individual moves. The thoracic region of the back requires a backrest that is capable of providing an increasingly concave surface as one reclines further backward, while the lumbar region requires a surface that is capable of increasing in convexity. Chairs which feature a single-plane surface, cannot provide this type of support.

In contrast, a dynamic backrest, one with a changing surface contour, will ensure that the back is supported in all natural seated postures. Knowledge gained from this study of motion can lead to a design solution that addresses the complexities of human movement and one that provides more comfortable and healthy seating than do conventional chair designs.

References

Adams M.A. 1983, The effect of posture on the fluid content of lumbar intervertebral discs. Spine, Volume 8, No. 6

Bendix T., Winkel J., Jessen F. 1985, Comparison of office chairs with fixed forwards of backwards inclining, or tiltable seats. European Journal of Applied Physiology, 54: 378-385

Chaffin D.B., Andersson G.B.J. 1984, Occupational Biomechanics, New York, (John Wiley & Sons)

Eklund M. 1967, Prevalence of musculoskeletal disorders in office work. Socialmedicinsk, 6, 328-336

Grandjean E. 1980, Fitting the Task to the Man, Third Edition, (Taylor and Francis, London)

Holm S., Nachemson A. 1983, Variations in nutrition of the canine intervertebral disc induced by motion. Spine, 8(8):866-874

Hult L.1954, Cervical, dorsal and lumbar spine syndromes. Acta Orthopaedic Scandinavia (Supplement 17)

Kelsey J. 1975, An epidemiological study of the relationship between occupations and acute herniated lumbar intervertebral discs. International Journal of Epidemiology, 4, 197-205

Kroemar R. 1994, Sitting at the computer workplace. Hard Facts about Soft Machines: The Ergonomics of Seating. Edited by Lueder R. and Noro K., (Taylor & Francis, London), 181-191

Lawrence J. 1977, Rheumatism in populations. (London: William Heinemann Medical Books Ltd)

Magora A. 1972, Investigation of the relation between low back pain and occupation. 3. Physical requirements: Sitting, standing and weight lifting. Industrial Medicine, 41, 5-9

Reinecke S., Bevins T., Weisman J., Krag M.H. and Pope M.H. 1985, The relationship between seating postures and low back pain. Rehabilitation Engineering Society of North America, 8th Annual Conference, Memphis, Tenn.

Schoberth H. 1962, Sitzhaltung, Sitzschaden, Sitzmobel. (Springer-Verlag, Berlin)