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The Chest Band in Human Posture Research

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INTRODUCTION

Since more and more people are assuming a sitting position during work, greater emphasis should be placed on the importance in the workstation layout of the design of the chair. The seat of a chair is intended to take the weight of the body off of the feet, provide a stable support for the sitter, and be comfortable. Suitability of a chair design depends on the type of work and surrounding workplace; the work task affects what postures are assumed, what resulting loads act on the body, and partly also the pressures on various parts of the body (Eklund, 1987). For a seated person, support is provided mostly by the buttocks and thighs. The ischial tuberosities, also referred to as the sitting bones, sustain the majority of the weight, and the soft tissues covering these bones are subjected to extremely high pressures which can lead to discomfort and pain. In order to prevent problems of high pressure areas under the sitting region and, therefore, prevent pain and discomfort, and in extreme cases, formation of pressure sores and cardiovascular problems due to restriction of blood supply to the buttocks, it is desirable to distribute the pressure as evenly as possible over the entire sitting region (Treaster, 1987).

The seat, which carries about 80-95% of the body weight, also influences the posture of the body (Mandal, 1981). A criterion for an ergonomic evaluation of a chair design describes that the spinal posture should neither be flexed nor extended for long periods of time. Excessive loading of the back for many hours during the day can lead to long lasting strain. In order to prevent backaches, this strain should be reduced. By maintaining a lumbar lordosis and an upright head during sitting, the most advantageous posture is achieved, excessive loading on the spinal column many be avoided and damage to the spine prevented.

How the spine will be affected is important to consider in sedentary tasks. By changing the chair design, it is possible to alter the responses of the spine (Eklund, 1987). A chair should be designed to provide a form of sitting that maintains lumbar lordosis and an upright trunk and head with minimal muscular work. At the same time, it should decrease pressure under the buttocks and thighs while still providing a stable support. By reexamining the workplace and the type of work being performed there, changes can be made to the chair components and the layout to improve the working conditions for the seated individual. Necessary to attaining this goal is the study of the anatomy of the seated person, the forces acting on the body from sitting and how chairs can affect the posture. These questions prompted the current study and its objectives, which are: to determine how the pressure distribution under the sitting region varies with seat tilt angle and to examine the corresponding postural changes associated with different seat tilt angles during relaxed, unsupported sitting.

METHOD

Instrumentation

To study the effect of seat tilt on the body, a chair was built to allow for changes in the seat pan angle. A wooden chair was taken apart and reconstructed, leaving the wooden frame intact and replacing the seat with a one-inch thick square piece of Plexiglas measuring 18 inches on its side. The seat was hinged at the back corners and adjustments to the angle of seat inclination were made with a hydraulic jack situated under the anterior edge of the seat. A steel pipe attached to the top of the jack spanned the length of the seat, providing support and a uniform change in the tilt. An adjustable backrest was also designed into this experimental chair, but since it was unsupported sitting which was examined, the backrest was not utilized and, therefore, removed from the chair.

A pressure measuring seat mat, purchased from Novel Electronics Inc., Minneapolis, MN, was used to record the pressure distribution under the sitting region. The EMED seat mat, measuring 45 cm x 45 cm, consisted of a 28 x 28 array of capacitance-type pressure transducers, converting changes in capacitance to changes in pressure in units of N/cm^2. An individual sensor had an area of 2 cm^2 and the active measurement area of the seat mat was 1568 cm^2. Pressure readings were collected with a Hewlett Packard Vectra 386 central processing unit.

The EMED software used to analyze the readings included EMEDDEMO, which provided changes in the pressure values of each sensor over time, and EMED SF, a package used to obtain graphical representations of the pressure distributions as well as the maximum pressure, force and area variances as a function of time.

The seat mat was secured to the seat pan with velcro fasteners to ensure that the mat did not move between different experimental runs and subjects and, therefore, maintain uniformity of the readings. A line drawn on the mat marked a boundary to which the subject's buttocks approached.

An External Peripheral Instrument for Deformation Measurement (EPIDM), or chest band, was used in this experiment to measure postural changes with differing seat tilt angles. This chest band was originally developed by the National Highway Traffic Safety Administration (NHTSA) to measure local displacements of the chest during frontal impacts. Initially designed to be used in a closed loop fashion, changes were required in order to enable the band to be used as an open-ended and straight measuring device.

The band consisted of strain gauges affixed onto a high carbon steel alloy strip measuring 140 cm x 1.25 cm x 0.025 cm. A data channel comprised a set of strain gauges, located two inches from one another, set up as a four-arm Wheatstone bridge. The information from each gauge, or channel, depicted the curvature along the back at that specific point on the chest band. A total of sixteen strain gauges were used in this experiment.

Subjects

Seven subjects, two female and five male, volunteered for this experiment. The ages of the volunteers ranged from twenty-one to sixty-seven years old. No subjects self-reported any back or any other neuromusculoskeletal problems. Relevant information about the subjects is shown in Table 1. To study the changes in the spinal posture and pressure distribution under the buttocks, it was desirable to have as little as possible between the measuring devices and the regions of the body under investigation. The female subjects were asked to wear shorts and a sports bra and the male subjects were asked to wear solely shorts.

Table 1: Subject Data Table

Subject	Sex	Age	Height (cm)	Weight (kg)
B1-B3	F	21	169	56.7
G1-G4	M	23	179	74.8
K1-K2	M	67	178	63.5
L2-L3	M	33	173	65.8
M1	F	22	175	65.8
Y2-Y5	M	58	165	63.0
Z2-Z3	M	46	169	68.0

Procedure

Prior to the experiment, the procedure and rationale for performing the test were explained to the volunteer. The experimenter measured and recorded relevant anthropometric data and vital statistics pertaining to the volunteer. Once all measurements were taken, the chest band was placed on the ground and zeroed. Double-sided sticky tape was then affixed to the band and prepared for placement on the subject's back. During this time, the pressure mat was zeroed. The seat was positioned at the appropriate angle and this angle was measured with an inclinometer located on the seat. Since the test runs began with a seat pan angle of either +10° or -10°, the tilt angle was adjusted to one of these positions. The subject was then asked to sit on the seat. The experimenter ensured that the subject was seated in the center of the pressure mat and seat with his/her posterior boundary meeting a visible mark made a few centimeters from the posterior edge of the pressure mat. At this time, adjustments were made to the footrest height to make sure that the feet were resting lightly on the footrest and not dangling in the air, and that the thighs were comfortably resting on the seat without any visible undue compression. Figure 1 illustrates the layout of the experimental setup.

After the subject was correctly positioned in the seat, the chest band was attached to the subject's back, as shown in Figure 2. The first, or uppermost gauge was positioned at the occipital protuberance of the skull. The lowermost gauge was positioned at the L5-S1 level and the number of this gauge was recorded. The experimenter responsible for placing the chest band on the

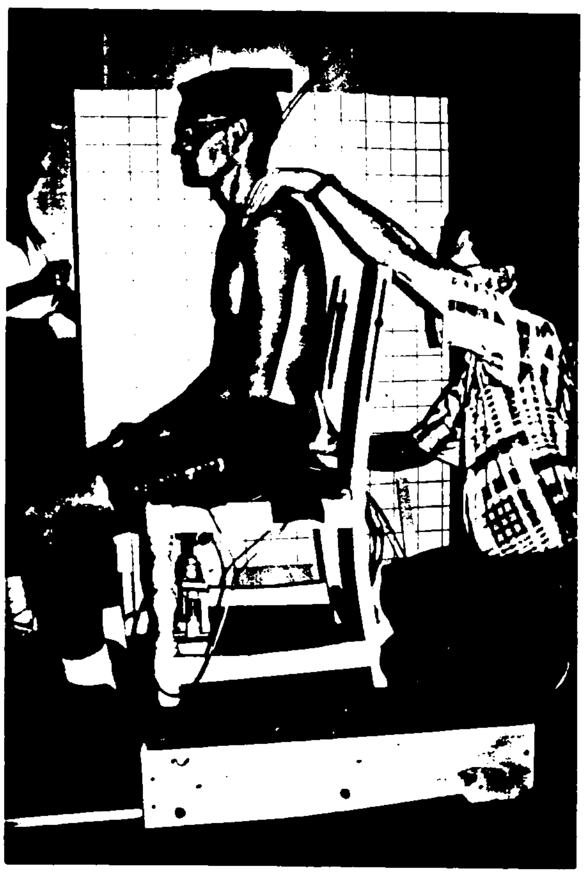


Figure 1: Experimental setup.

Figure 2: Placement of chest band on subject's back.

volunteer's back, also was responsible for making sure that the band remained flush with the skin, sometimes gently holding it in place at its upper and lower extremes. After the chest band was securely attached to the skin, the measurements were ready to be taken. The subject was asked to sit comfortably in the chair with no conscious neuro-muscular control of the posture. An unsupported, relaxed, upright position was assumed, eyes focused straight ahead, hands resting on the thighs, and the seated body was stationary during the test.

Before beginning the test, time was allowed for the subject to find his/her resting equilibrium. Once this equilibrium was attained, the data acquisition was ready to begin. At a signal, pressure readings from the seat mat and curvature readings from the strain gauges in the chest band were simultaneously recorded. At certain seat tilt angles, namely +10°, +5°, 0°, -5° and -10°, a photograph of the subject seated in the chair was taken. Data was sampled for five seconds.

Upon completion of sampling, the chest band was slightly detached from the lower back so that the subject would be able to make slight adjustments to his/her sitting posture without feeling constrained by the rather stiff band. While the subject remained seated in the chair, changes were made to the seat tilt angle with the hydraulic jack system built into the chair. An inclinometer was used to measure the seat tilt angle. The footrest height was adjusted. Wooden planks were used for these height adjustments; between 2° tilt changes, 3/4 inch planks were added to or removed from the stack whereas between 1° tilt changes, 1/4 inch planks were added or removed. Again, the subject was asked to find his/her static equilibrium and adjust his/her body to the new seat position. The chest band was reattached to the lower back in preparation for the next run.

These steps were repeated until all thirteen test runs were completed. These thirteen different test positions comprised the different seat tilt angles, which were varied from +10° (forward) to -10° (backward) in increments of 2° and including +5° and -5°. Once all the seat tilts were tested, the chest band was carefully removed from the subject's back. All the data was saved on the hard drives of the computers as well as on floppy disks.

The experiment was repeated four weeks later to check the test-retest reliability of the measurements and to determine whether any changes occurred over time. The same subjects were used in this second experiment and the tests were run at approximately the same time of day, only a little later during the second round. The same protocol was followed however, a different experimenter administered the chest band portion of the experiment. The subjects' spinal posture was also measured in the standing position so that a comparison could be made between standing and various sitting postures.

RESULTS

Although there were a total of thirteen seat pan angle positions, the results from only five of these positions, particularly +10°, +5°, 0°, -5° and -10°, will be examined. A positive sign (+) denotes a forward-tilted seat and a negative sign (-) denotes a backward-tilted seat angle. With respect to the pressure measurements, a few patterns were observed between different subjects and also within each individual subject. Since there was variation in age, sex and body size and distribution among the subjects, each subject was used as his/her own control.

A trend was evident in a majority of the tests: the highest magnitude of the maximum pressure (Pmax) was attained with the backward-tilted seat angles. Maximum pressure values at different seat tilt angles are shown in Table 2. Despite the vicissitude of the Pmax readings in the three tests depicted in Table 2, there was a general increase in Pmax as the angle was changed from a forward- to a backward-inclined seat.

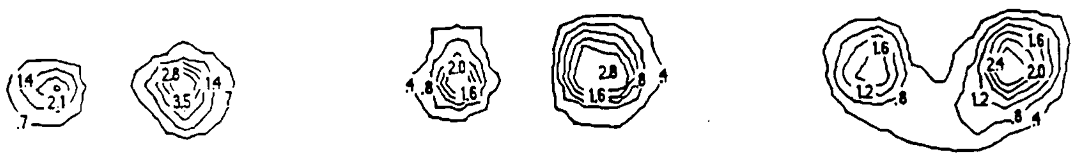
In the seated pressure measurements, the pressure was distributed over the greatest area with the forward-tilted seats. Along with increasing the area of the sitting region, the forward-tilted seat angles also brought about a more uniform pressure distribution with fewer localized high pressures over the

Table 2: Maximum Pressure and Area Values

Seat Angle (°)	Pmax (N/cm^2) B1	Pmax B2	Pmax B3	Area (cm^2) B1	Area B2	Area B3
+10	2.9	2.3	3.6	232	280	232
+5	2.7	2.8	5.3	184	232	144
0	3.8	3.5	5.9	152	168	120
-5	3.1	4.9	4.5	144	160	112
-10	4.1	5.3	6.3	168	184	112

ischial tuberosities. Changes in area with differing seat tilt angles are found in Table 2. Contour maps graphically representing the changes in pressure values and distributions with varying seat tilt angles are shown in Figure 3.

Curvature-displacement (k-s) graphs generated from the chest band data follow a pattern in which the curve at the lower back tends to flatten as the seat angle is tilted backward. Curvature here corresponds to the radius of curvature at distinct locations, separated by equal displacements, along the length of the chest band. Figures 4, 5 and 6 illustrate the changes in the k-s curves for seat tilt angles of -5°, 0° and +5° and also compare these curves with a standing k-s curve. Work is in progress to convert these k-s curves into displacement graphs representing the actual shape of the spine in different sitting positions.



a b c

Figure 3: Contour maps of smoothed pressure intensities on a seat pan with an a) -5° backward tilt, b) 0° horizontal and c) +5° forward tilt seat angle.

DISCUSSION

This experiment was conducted to study the simultaneous changes in seated pressure distribution and spinal posture to alterations in seat pan angle during relaxed, unsupported, upright sitting. In general, a forward-inclined seat tended to provide the greatest contact area under the seated region, i.e., the lowest magnitudes for maximum pressure and a more uniform pressure distribution with fewer localized high-pressure areas under the sitting bones.

Visible physical changes were observed with different seat tilt angles. Whereas the backward-tilted seats forced the seated individual to assume a "slouched" posture, the forward-tilted seats, especially the +5° and +10° tilt angles, allowed the subject to sit in a more "upright" position. Preliminary

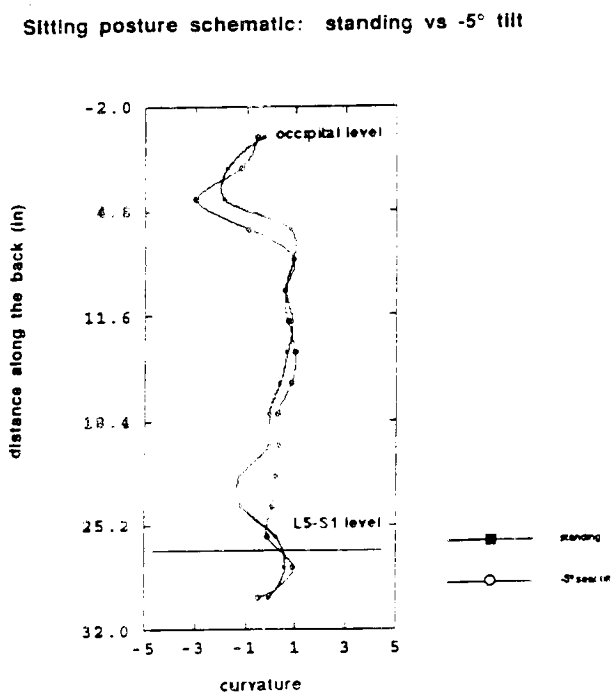


Figure 4: Curvature-displacement curve: standing vs -5° seat tilt.

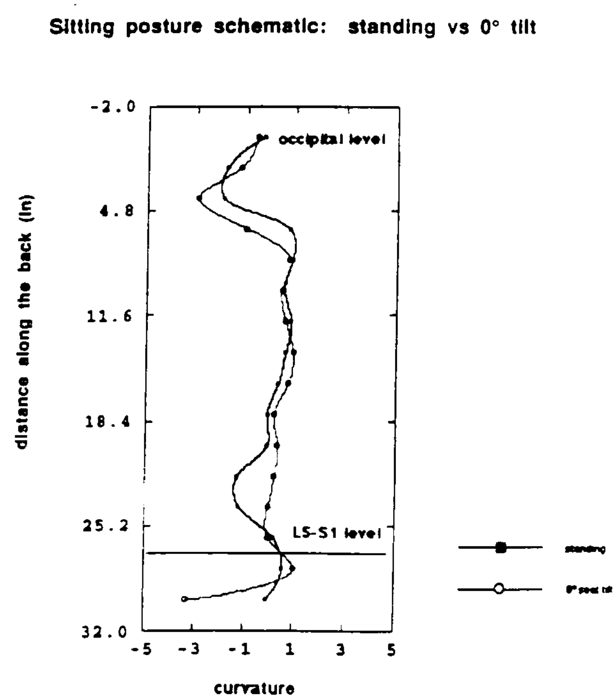


Figure 5: Curvature-displacement curve: standing vs 0° seat tilt.

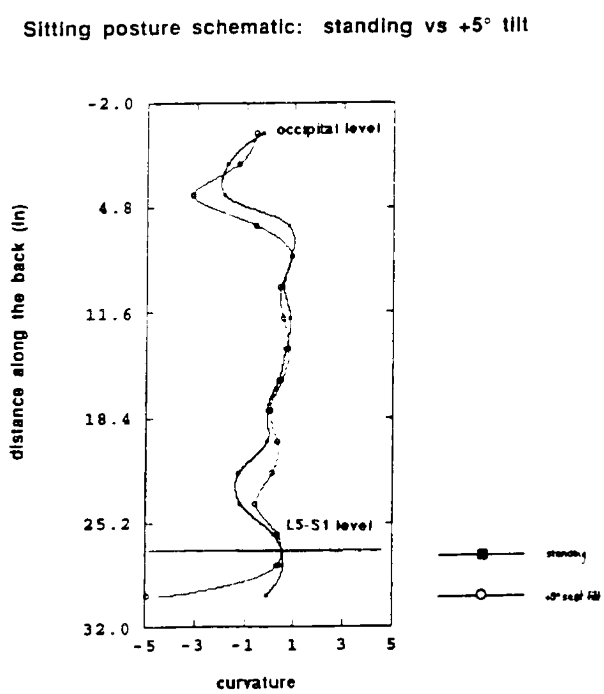


Figure 6: Curvature-displacement curve: standing vs +5° seat tilt.

results from the chest band data demonstrate a flattening of the k-s curve at the level of the lumbar spine for the backward-tilted angles. Work is in progress to show that the normal lumbar lordosis with forward tilt will flatten with a horizontal and backward-tilted seat.

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DISCUSSION

PAPER: **The Uses of the Chest Band for Spinal Posture Research**

PRESENTERS: Y. King Liu, A. Bodnar, N. Yoganandan, Frank Pintar

QUESTION: Dr. Levine, Wayne State University
Are you implying, first of all, that lordosis is better than lumbar spine worsening.

ANSWER: There appears to be considerable evidence that, for example, from the work in Sweden at least, for example, as far as the disk pressure is concerned, standing is 100% and sitting is 150 to 190%. Yes, that is my fundamental hypothesis, that the maintenance of no more lumbar lordosis is better than the flattening of the same.

Q: Then how come most people with back pain, who we see quite a few of, prefer to sleep with their spine flexed in the fetal position and why is William's exercise which is reflection work also?

A: Well that is an argument that is on-going. I guess the answer to that question is it depends on where the neuro susceptors are in terms of whether it is discogenic, whether it is in the facet region or whether it is in the subchondral bone, etc. etc.

Q: Guy Nusholtz, Chrysler Corporation
How did you attach your chestband to the spine?

A: It is attached with a double-sided tape, OK, and when the experiment, one portion is there, then once the patient gets up, we peel off the tape and reattach the tape for the second position.
That's all.

Q: Did you have any problems with it sliding off during your experiments or did it pretty well stick to the skin?

A: It pretty well sticks to the skin and also, one of the experimenters applied a very minor pressure to the lumbar and the cervical spine region.

OK, thank you.

Q: Joe Balser, General Motors
What is your opinion of riding long distances on a bicycle, as far as posture and potential injury to the spine?

A: According to the Keegan paper, which is the radiographic study, bending over, if I assume from your question, also flattens the lumbar spine and if the hypothesis is correct that the maintenance of lumbar lordosis is a desirable state of affairs, then it is not that good for the lumbar spine.

Q: Do you think there is a large impact problem in bicycle riding as far as the variable loads that you see during the ride?

A: Well, with respect to the impact room, I don't know. Ours is not an impact study. It just has to do with posture so it is a static study. In terms of the straightened lumbar spine and where the loads is coming, mainly say, vertically, I don't know the answer to that question.

Thank you.